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# **RHCV Telescope System Operations Manual**

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**Warfighter Interface Division  
Battlespace Visualization Branch**

**January 2018**

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# 1 Summary

The purpose of this document is to describe and record the methods required to safely and successfully operate the RHCV 17" PlaneWave telescope system.

The telescope system is an aggregation of hardware and software components. Several of the components are closely coupled and rely on one-another, while others are largely independent. This document:

- outlines the system architecture,
- identifies the significant components in each subsystem, and
- presents the steps necessary to safely use the telescope system by identifying the major use cases by capability, describing the steps involved in each use case.

Some software versions, and some hardware and software components, will change over time. However, it is expected that the overall functionality (use cases) will remain the same. This means that the specific steps highlighted in this document may need to be modified by the operator to correspond to newly added, replaced, or upgraded hardware and software, but the concepts highlighted in the use cases should still apply.

The major use cases covered include:

- General safety guidelines
- Pre-use safety inspection
- General hardware startup
- General software startup
- Attaching a camera or eyepiece
- Camera setup and configuration
- Manual telescope controls
- Tuning pointing accuracy
- Loading TLEs for satellite tracking
- Dome control and alignment
- Tips for collecting CCD images
- System shutdown procedures
- Building a mount model (advanced)
- Topics to cover for telescope attendant training



Figure 1-1: HEAT Observatory Overlooking Dayton

The use cases are briefly described in separate sections, and step-by-step instructions are presented. Each section begins on a new page so it can be easily printed as stand-alone documents if needed.

There are also appendices covering executive startup and shutdown procedures (for those already familiar with the system who would like to use a simple checklist) and instructions on how to align the telescope and configure the camera for capturing images of geostationary satellites. Representative printable log sheets are also included at the end of the document.

## 2 Background

The 711 Human Performance Wing's (711 HPW) Battle Space Visualization Branch (RHCV) requires a diverse collection of ground-based satellite images for research involving space situational awareness (SSA) and advanced visualization. The objective of this research is to develop and demonstrate a native (in-house) end-to-end SSA capability to directly collect, process, analyze, and display ground-based images of satellites and space phenomena. These data will be utilized as inputs into branch human-in-the-loop SSA and visualization research activities. The research involves the selection and installation of an appropriate collection of imaging hardware, software, and computational components that will make up a research image collection and processing testbed.

In addition to providing timely and applicable research data, the Battle Space Visualization Branch has an improved ability to demonstrate the nature of the research cycle, from initial data collection, through processing and analysis, and into the SSA and visualization research products.

The observatory contains these hardware and software components:

Telescope: PlaneWave Corrected Dall-Kirkham (CDK) Astrograph

- Lat: 39.7937546      Lon: -84.0922699      Alt: 281m
- Diameter: 17-inch (432mm)
- Focal Length: 2939mm (115.71"), f/6.3
- *Specially coated optics for signal collection from 250nm-2500nm*
- Carbon fiber open truss optical design that minimizes focus shifts caused by thermal expansion
- 82 degree field of view
- Environmentally protected within a 3.5m ObservaDome

Cameras: SBIG STF-8300M (monochrome) & ST-8300C (color)

- Imaging CCD Kodak KAF-8300
- Imaging/Pixel Array 3326 x 2504 pixels
- CCD Size 17.96 x 13.52 mm
- Total Pixels 8.3 million
- Pixel Size 5.4 x 5.4 microns square

Filters: 8-Position Filter Wheel for 36mm Filters (SBIG FW8-8300)

- 36mm Filters – (Baader Planetarium)
- R (~350-550nm, 98% transmission)
- G (~490-575nm, 98% transmission)
- B (~587-687nm, 98% transmission)
- L (400-680nm, 98% transmission)
- H-alpha (7nm bandpass)
- S-II (8nm bandpass)
- O-III (8.5nm bandpass)

Commercial Software (Microsoft Windows-based):

- The Sky X Pro (graphical user interface)
- MaxImDL, CCDOps, and CCDSoft camera software

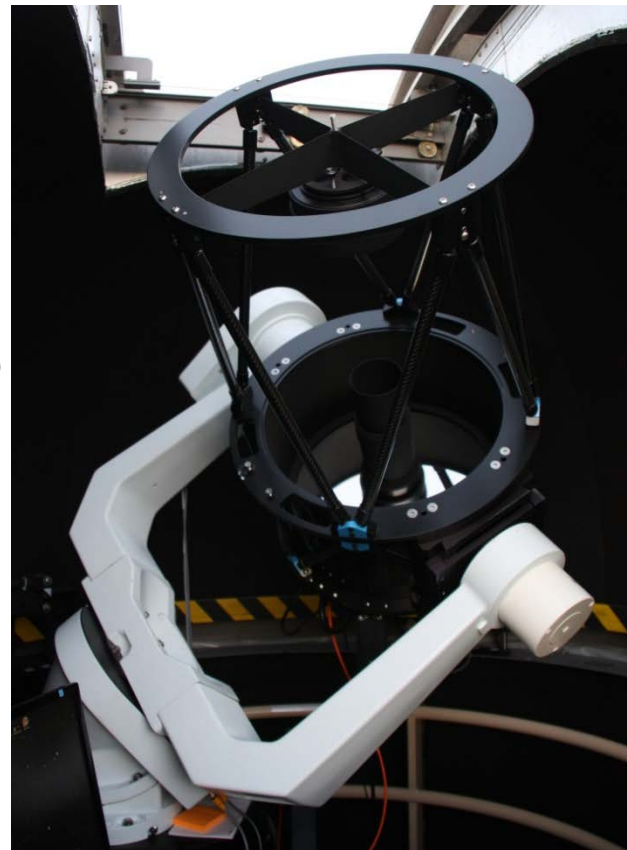


Figure 2-1: Telescope OTA and Fork Arms



### 3 System Software Architecture

The observatory software system consists of a collection of components from multiple vendors and sources. Key operational software components include:

- TheSkyX Pro – the GUI
- STI – telescope mount interface and ASCOM drivers (alternative manufacturer driver: SiTechExe)
- Dome – dome GUI and controller interface (python-based, developed in-house)
- PWI – PlaneWave Hedrick focuser interface and ASCOM drivers
- MaxImDL – preferred commercial camera control software; *required* for autofocus and advanced mount model configuration (alternative commercial software: CCDSoft)

Most of the components can communicate using the Astronomy Common Object Model (ASCOM) protocol when running in a Microsoft Windows environment. The figure depicts the general system control architecture.

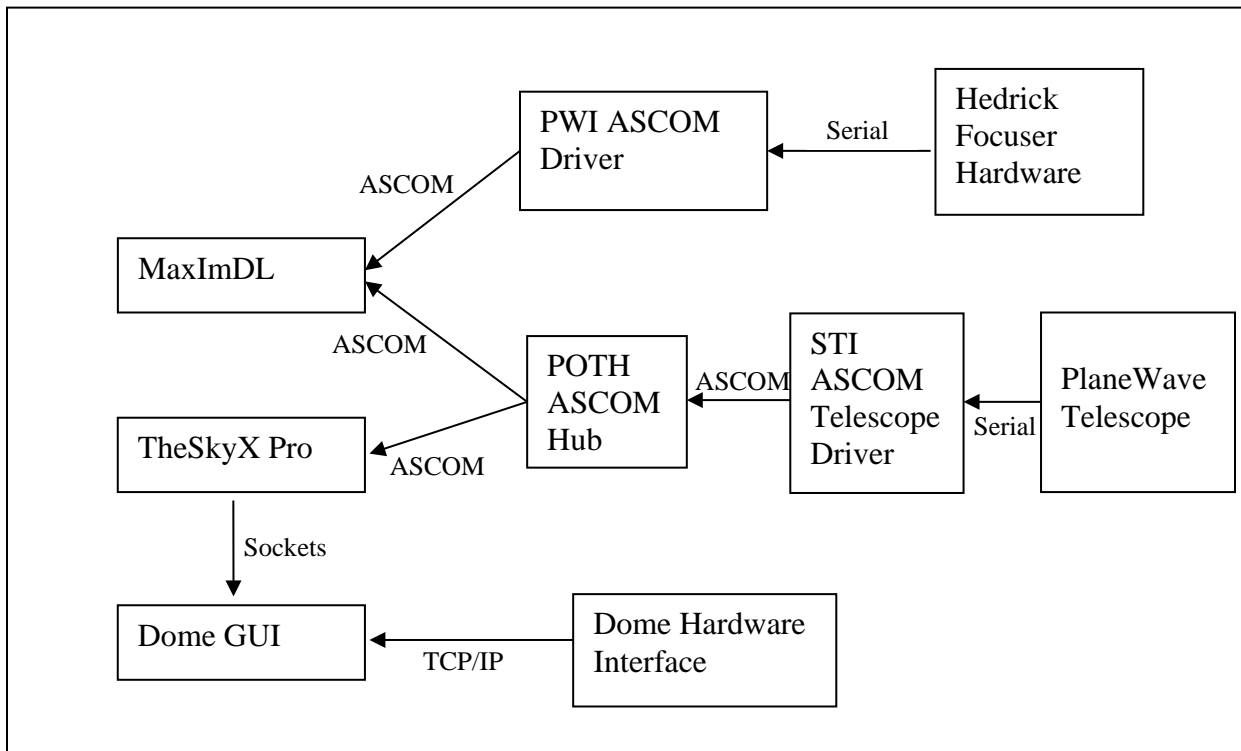


Figure 3-1: Observatory Control Architecture on Control PC

System components must be initialized (and shut down) in a specific order to ensure overall system integrity, and because of the communication mechanisms between the applications. Note the coordinated communication of TheSkyX Pro and MaxImDL through the POTH ASCOM hub, which allows telemetry information to be shared between the STI telescope controller and all of its connected components. This allows telescope and observational metadata to be automatically included into the FITS images collected by MaxImDL.

(Ultimately, it would be nice to replace the Microsoft-only components with platform-independent pieces; we have the serial protocols for both the telescope and the focuser in case we can find or write our own controller code. For now, we need to use the ASCOM drivers, which will only run in Microsoft Windows.)

## 4 General Observatory Safety Guidelines

Please pay special attention to these general observatory operational safety guidelines.

### 4.1 The Control Area

- Do not walk beneath the raised platform indicated by the yellow outline painted on the floor.
- Use caution when walking around the scope; the cable cover running beneath the lift may present a tripping hazard.
- Follow all basic computer guidelines to prevent repetitive strain injuries.
- If working in low light use a darker Windows theme to prevent eye strain.
- If snacking, clean up any messes immediately – the lab's roaches and mice are fearless.

### 4.2 The Telescope

- Never use any part telescope to climb or catch your balance. If it shifts, breaks, or falls on top of you, you will be worse off both physically and financially.
- The telescope has two degrees of freedom, take note of them and their pinch points and never put anything near those pinch points.
- The optical tube assembly (OTA) connects to the fork by friction dovetails. If the OTA slips in the dovetails, immediately return the scope to a horizontal position if possible, turn off all power, and notify the appropriate POC. Do not use the scope until it is repaired and inspected.
- The telescope is always slowly moving while it is tracking, and has several protruding attachments. Be mindful of its position and the position of its attachments when moving near the telescope.

### 4.3 The Lift

- When raising or lowering the platform:
  - Keep hands, feet, and all objects and equipment inside the platform railing at all times.
  - Attach the safety chains at the platform entrance when riding the lift.
- Do not climb or sit on the lift railing.
- Always verbally and loudly announce lift platform operation before motion is initiated in any direction.

### 4.4 The Dome

- When active, the dome can move rapidly and without warning.
- There are four big red emergency stop buttons all around the dome. Make sure you can locate them!
- There are many pinch points near the dome's friction drive ring (the yellow and black safety tape):
  - Do not lean or grab the friction drive ring when the dome is energized.
  - Stay away from the drive motor, tire, casters, and brackets that move the dome.
  - The dome eats loose hair, ties, clothing, and anything attached to it. Don't let it have yours!
- The dome's shutter doors open and close symmetrically. If you'd like to keep your hands symmetrical, be careful where you put your fingers when operating them.

## 5 Pre-Use Safety Inspection

The purpose of the pre-use safety inspection is to ensure that the telescope system can be operated without damaging any of its components or endangering the user. Please use these steps as a starting point before operating the system, and augment these steps with your own research-specific safety requirements.

- 1) Weather – Check the weather before you begin, and regularly throughout your session. (The catwalk can be used for this purpose.) If the weather changes quickly, close the dome immediately and execute the appropriate shutdown procedures.
- 2) Cabling – Inspect the cabling on the telescope platform, especially the camera and telescope control cables that will move when the telescope mount moves. Ensure that the cables will be able to move freely. Several control cables are attached to the legs of the scissor lift. If these are visible (if the lift is raised and you can see them), please check to see that the lift legs will not damage the cables when the lift is raised or lowered.
- 3) Lift – Ensure the ledges surrounding the lift are clear; otherwise, anything sitting on the ledge may fall or be smashed when the lift is raised to its full height
- 4) Hydraulics – Each time the lift is operated, make sure the green-handled manual release lever is fully engaged so lift hydraulic pressure can be maintained during operation.
- 5) Visitors – Ensure visiting personnel are fully aware of the safety hazards surrounding telescope and lift operation, and ask them not to touch any controls unless directed to do so.
- 6) Compressor – Turn off the air compressor when you finish using it. The emergency release on the compressor can be used to drain excess pressure from the tank once it is turned off.
- 7) Review – Review the general safety guidelines. Ensure visitors also review them if they will be present when the telescope or lift are operated.

**Please note** these special considerations regarding the use of the telescope:

**DO NOT EVER** leave the telescope unattended in tracking mode! You can press the “Stop” button on the STI GUI to halt tracking, or Park the scope using STI. Mount controller power can be left on if necessary.

**DO NOT EVER** leave the telescope oriented unattended in a vertical or near-vertical configuration of the optical tube (“pointing up”), whether or not power is applied to the controller. The dovetails holding the optical tube into the mount are friction-based, and you *truly* don’t want to risk that mechanical failure of the dovetails would drop the expensive optical tube (that you can’t afford to replace) onto the floor!

## 6 General Hardware Startup

This section outlines the steps for energizing all observatory equipment and preparing it for use. This section covers hardware initialization only; software initialization is *not* included in this section.

**\*\*\* Check the weather conditions before you begin, and regularly throughout your session. \*\*\***

1. Ensure the scope & pump power disconnect switches are off, & unplug external monitor USB on the lift
2. Turn on air compressor
3. Reboot the Control PC and log in
  
4. Energize the scope and pump power disconnect switches (*after* the PC has booted)
5. Plug in the external monitor USB
6. Make sure the Dome Controller power is on (wall switch is near gray dome controller box)
7. Visually inspect cabling to ensure OTA and camera cables can move freely
  
8. If the OTA is not in its park position, use the hand controller to approximately level the OTA (the sole purpose of this instruction is to assist with dome alignment and synchronization)
  
9. If operating a camera attached to the OTA: check the thumb screws to ensure they are finger-tight
10. If using an eyepiece: check all knobs on the eyepiece assembly to ensure they are finger-tight
  
11. Ride the lift to the top (adhere to posted Observatory Safety Tips)
  
12. Start the Dome Control application
  - (a) Select “Connect Dome” button at the top of the application screen
  - (b) Rotate dome using the buttons at the bottom of the application until the shutter is accessible  
Be mindful of dome slippage; if the dome slips, please rotate it the other direction instead
13. Open the dome shutter (manually) by removing the pin and pulling the handles apart  
(The pin can be used as a lever to begin to open the shutters)  
Store the pin in the dome apron
  
14. Check dome tire air pressure, inflate to 50 PSI if required
15. Ride the lift down; do not lower the lift completely in order to avoid jarring the telescope
16. Turn off air compressor

Figures depicting some of these hardware components are included here:



Figure 6-1: Main power for lift outlets, including telescope

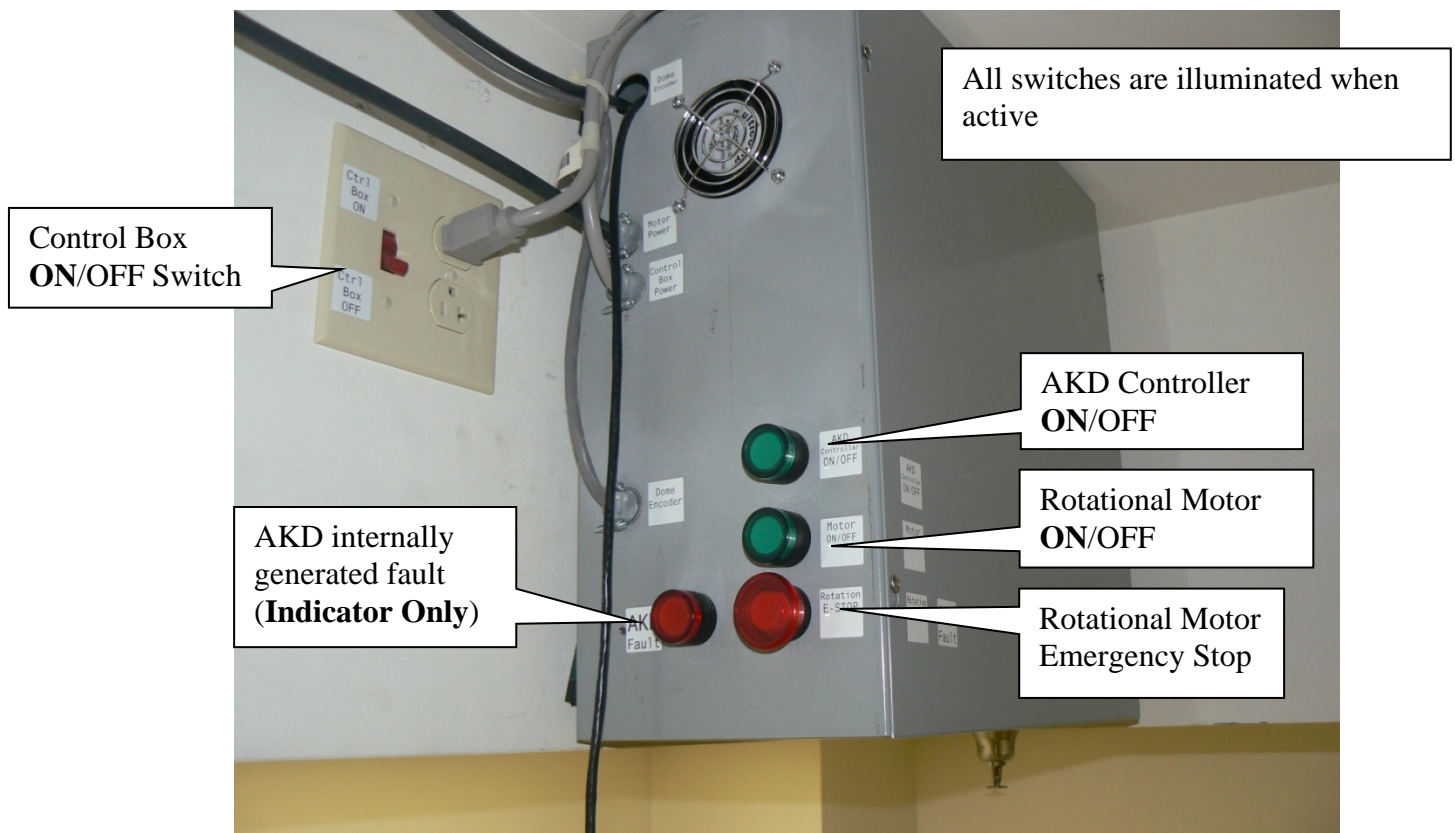


Figure 6-2: Automated Rotation Control System Enclosure

## 7 General Software Startup

This section outlines the steps necessary to initialize the telescope control software. At the conclusion of these steps, the system is ready for use, but may not yet be calibrated for a specific study. These steps only prepare the telescope system for use; instructions describing “how to use the telescope” once the control software is initialized are *not* included in this section.

This section assumes the use of MaxImDL camera control software, which has been configured as a master Observatory Control System, and starts several other system components via ASCOM protocols.

1. Start the MaxImDL application using the desktop shortcut
  - (a) Start Observatory dialog,
  - (b) Select “Connect All” to connect to STI (telescope control) and PWI (focuser)
  - (c) Close the Observatory dialog
2. Using the Dome Control application (start it if it is not already running)
  - (a) Select the “Connect Dome” button at the top of the application screen
  - (b) Use the Dome Controller’s *Left* and *Right* controls to center the shutters directly in front of the OTA  
Be mindful of dome slippage; if the dome slips, please rotate it the other direction instead
3. Using STI (the telescope control application):
  - (a) Select “Home” from the Command pulldown in the center of the screen
  - (b) Select “Initialize Scope Using Homing Switches” in “Homing Operations Window” dialog
  - (c) Wait for initialization to complete (“Idle” status on both axes), and press dialog’s “OK”
  - (d) Select “Start” in the center of the STI screen to begin telescope tracking
4. Start TheSkyX Pro application using the desktop shortcut
  - (a) Select “Connect Telescope” from Startup menu in Telescope tab
  - (b) Select “Look Up” icon on ribbon menu at the top right of the application screen
5. Using the Dome Control application: Select “Connect Scope”; Select “Sync”; Select “Autotrack”  
(NOTE: The dome may require additional positioning adjustments to ensure accuracy.)
6. If you will not be on the lift during operations, disconnect the remote monitor USB plug on the platform
7. Raise the lift – you may use either:
  - (a) the yellow hand controller attached to the hydraulic pump, or
  - (b) the lift controls on the platform

Figures depicting MaxImDL software startup settings are included here:

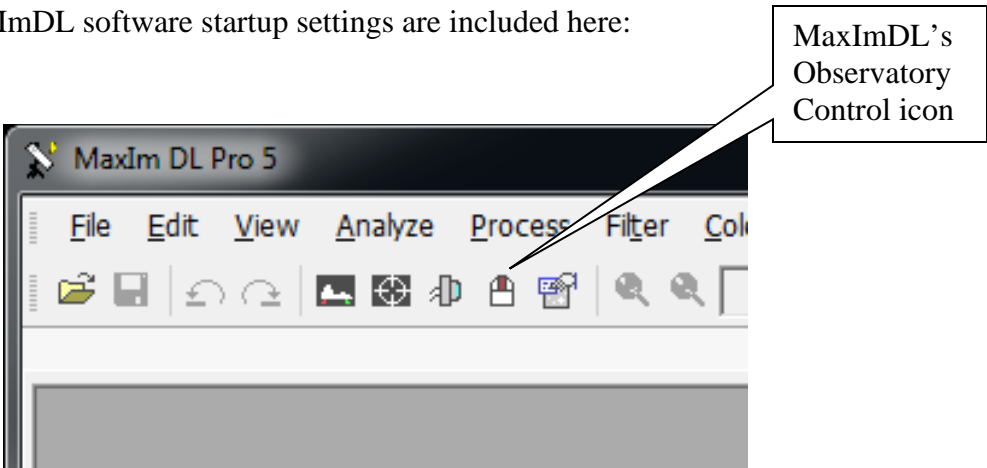


Figure 7-1: MaxImDL -- Observatory Control tool icon

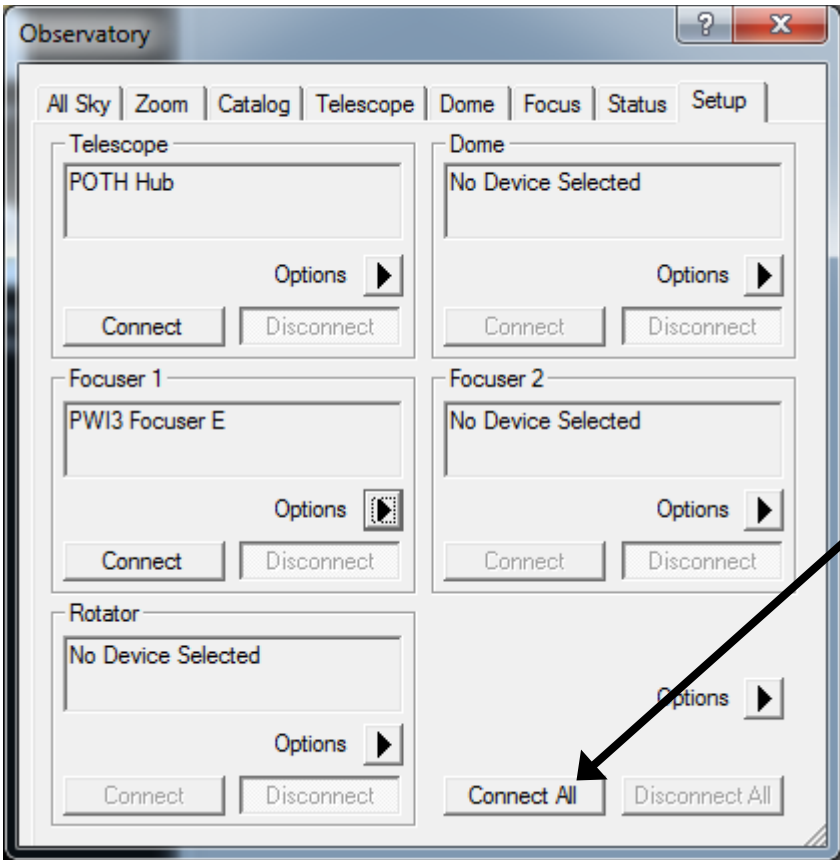


Figure 7-2: MaxImDL's Observatory Control window



Start TheSkyX Pro GUI should take up most of the screen, and look similar to this Figure:

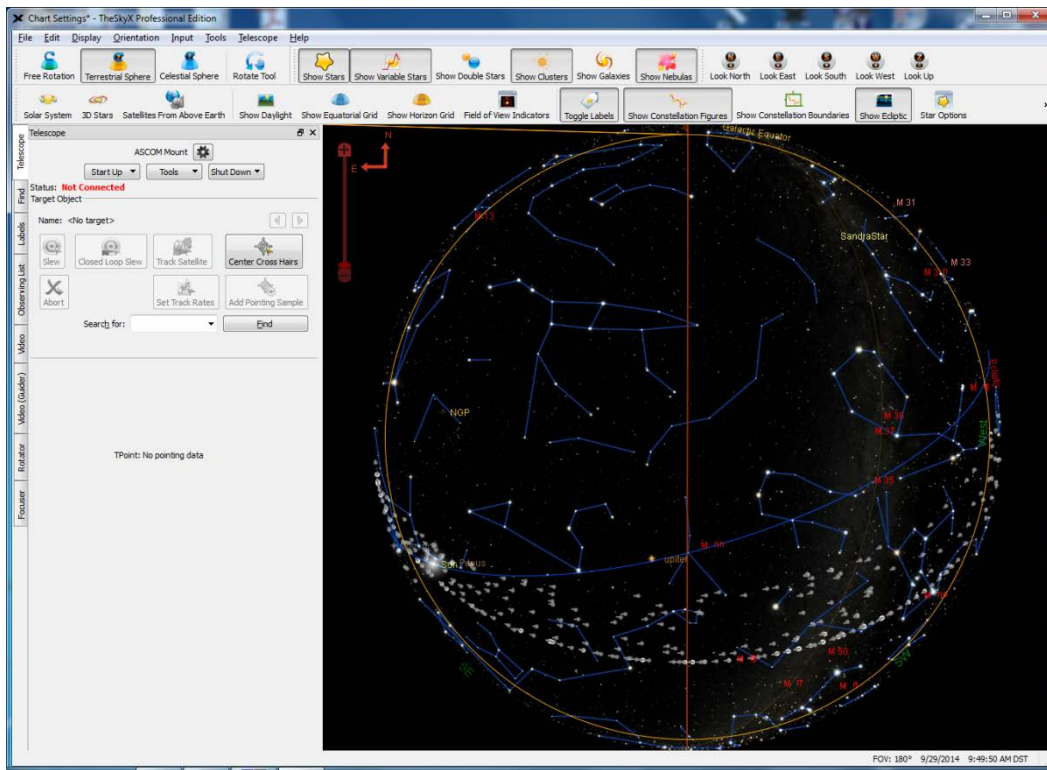


Figure 7-3: TheSkyX Pro at startup

The Dome Control Interface GUI will look like this when it is first started:

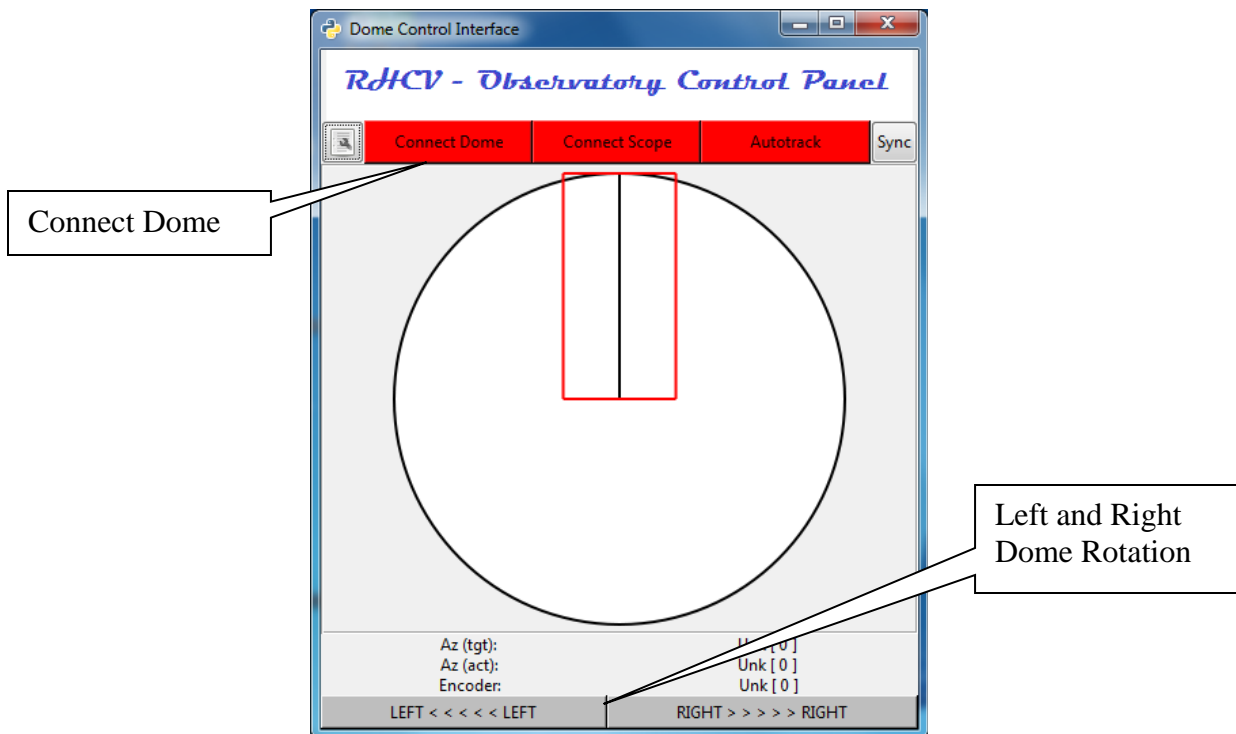


Figure 7-4: Dome Control Interface



Figures depicting the Homing process STI uses to initialize the telescope's mount model are included here:

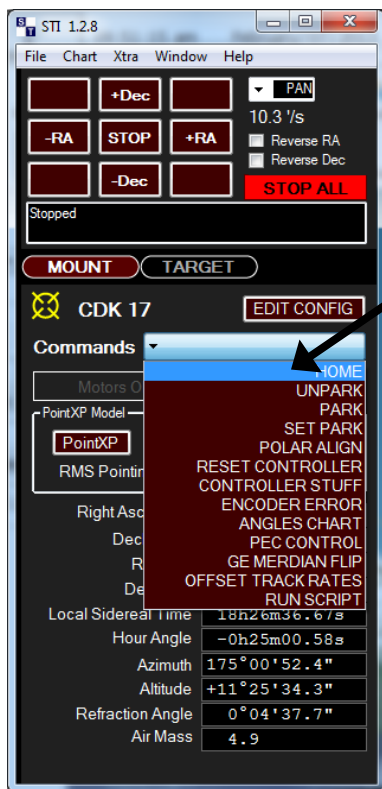


Figure 7-5: Step 1: STI Home Telescope

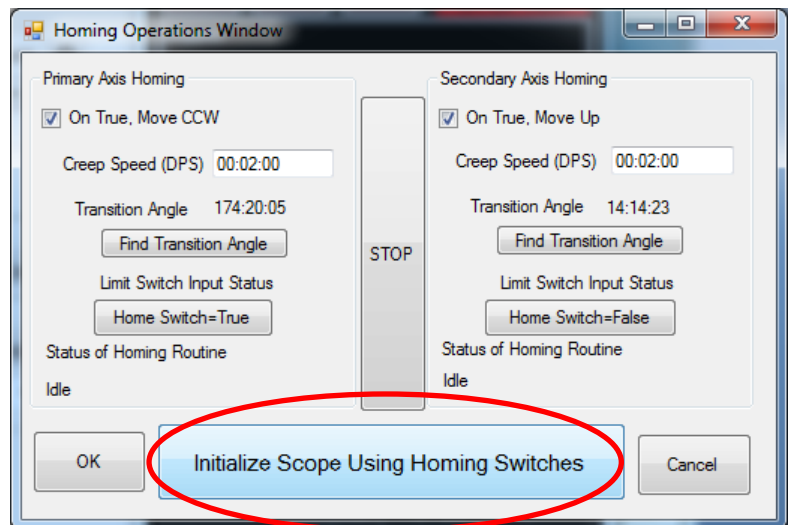


Figure 7-6: Step 2: Initialize Scope Using Homing Switches

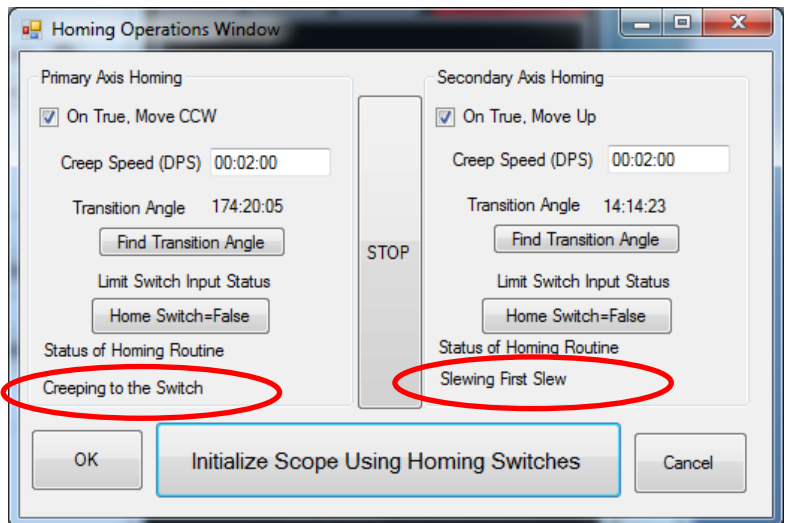


Figure 7-7: Step 3: Wait While Home Operation Completes

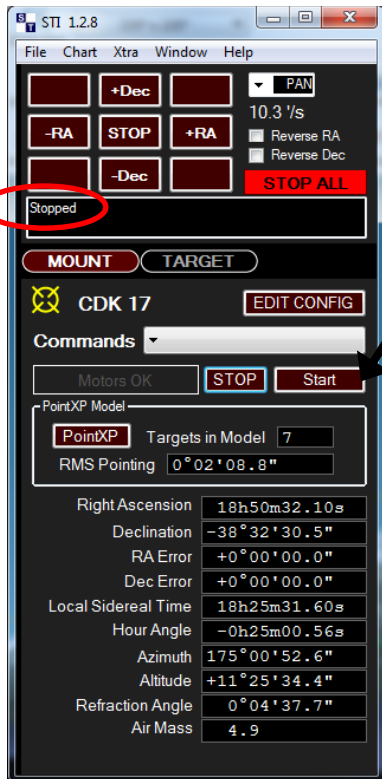


Figure 7-9: Step 5: Select "Start" for Tracking

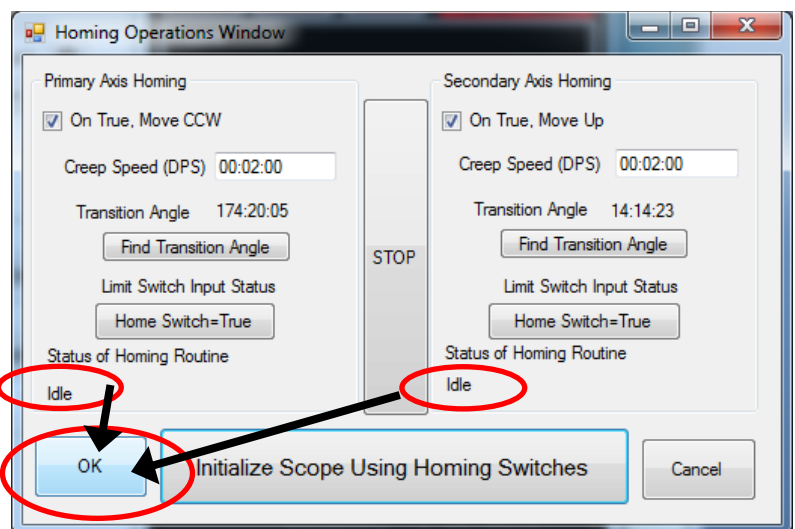
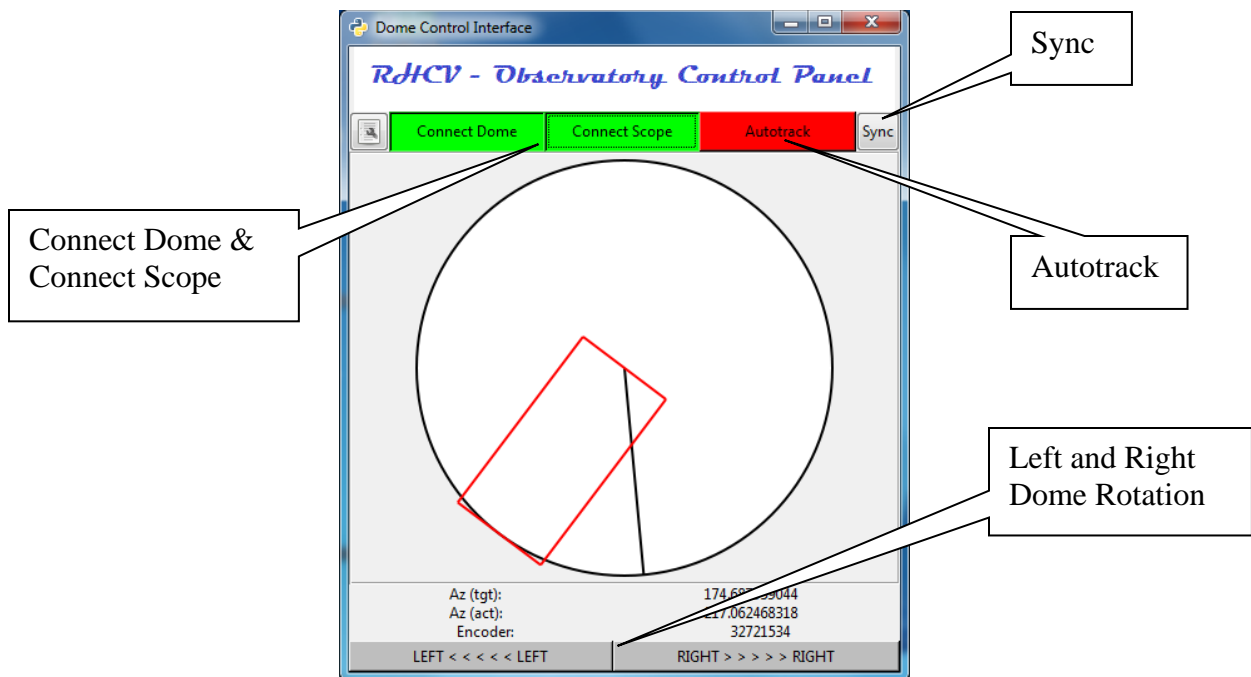
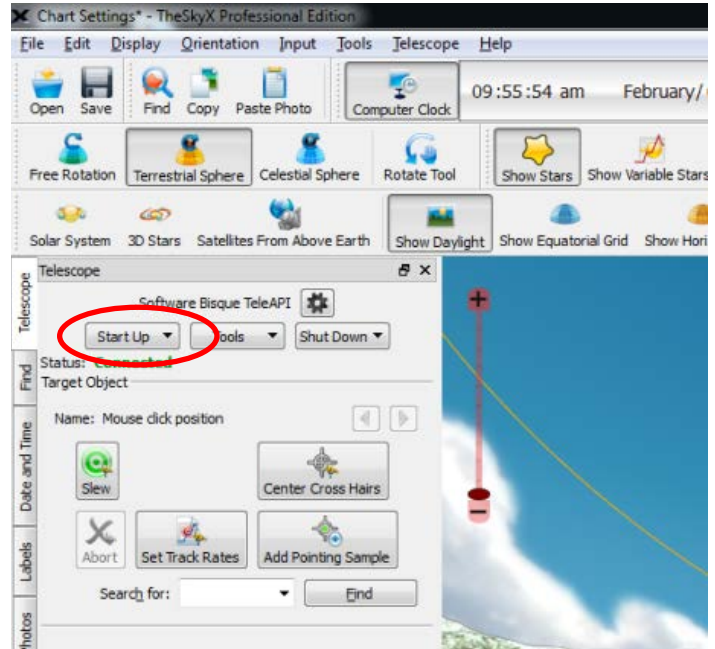
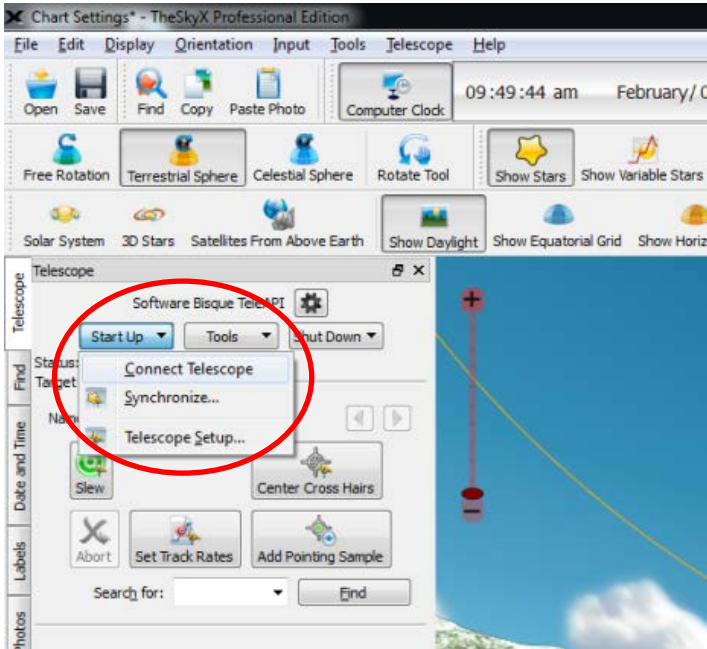


Figure 7-8: Step 4: Select OK After Both Axes Say "Idle"

A collection of Figures depicting these software settings are included here:

Select the Start Up pulldown menu on the Telescope tab at the left of the display, and choose “Connect Telescope.” The Sky will show the telescope mount’s current pointing position as a white concentric circle on the display. The pointing system has been initialized and is now ready for use.



## 8 Attaching a Camera or Eyepiece

This section describes the steps for physically detaching and attaching an eyepiece or preconfigured camera to the OTA. The camera to be connected to the system must have already been configured for use with the system (proper power, device drivers, etc.).

The SBIG 8300C camera (without filter wheel) and the SBIG 8300M (with attached filter wheel) have already had drivers installed on the control PC, so they *can* be attached using these procedures.

### 8.1 To remove an attached eyepiece

1. Use the telescope hand controller to move the OTA to a comfortable orientation.
2. While firmly holding the eyepiece assembly with one hand, loosen (but do not completely remove) the two (2) knobs on the 3.5" focuser.
3. Carefully slide the eyepiece assembly out of the 3.5" focuser tube. The tolerance is very tight, so it may be necessary to rotate the assembly while removing it.
4. Place the assembly in the box under the pier (where it will not be a tripping hazard).

### 8.2 To remove an attached camera assembly

1. Use the telescope hand controller to move the OTA to a comfortable orientation.
2. While firmly holding the camera assembly with one hand, carefully unscrew the two (2) small hex-head thumb screws that attach the camera spacer to the focuser. The screws should be finger-tight, but you may need to jiggle the camera assembly in order to prevent the screws from binding.
3. Do not remove the USB or power cables from the camera.
4. Place the camera face down in the box beneath the telescope pier (where it will not be a tripping hazard).
5. Attach the screws to a free hole in the back bezel of the OTA.

### 8.3 Attaching an eyepiece to the 3.5" mounting point

1. Use the telescope hand controller to move the OTA to a comfortable orientation.
2. Ensure the knobs on the 3.5" focuser are unscrewed so the tube is able to receive the eyepiece assembly.
3. Carefully insert the eyepiece assembly *completely* into the 3.5" focuser. The assembly includes (at least) a 3.5" to 2" adapter, and may also include an eyepiece and additional 2" to 1.25" adapter. The tolerance is very tight, so the assembly will need to be accurately aligned in order to guarantee a proper fit.
4. Tighten the two (2) 3.5" focuser knobs by hand. Check all other assembly knobs to ensure they are tight.

### 8.4 Attaching the SBIG camera assembly to the 3.5" mounting point

1. Use the telescope hand controller to move the OTA to a comfortable orientation.
2. Locate and remove the two (2) hex-head thumb screws from their storage location on the OTA bezel.
3. Align the spacer holes on the camera assembly with the corresponding holes on the 3.5" focuser.
4. Insert a screw at the top and bottom of the assembly, and hand-tighten the screws.
5. Since the tolerance is tight and the screws may bind, it may be necessary to jiggle the camera assemble while tightening the thumb screws. Using tools to tighten the screws is not required.
6. Note that the camera body must be oriented (aligned) with the OTA in order for imagery to be "correctly" framed.

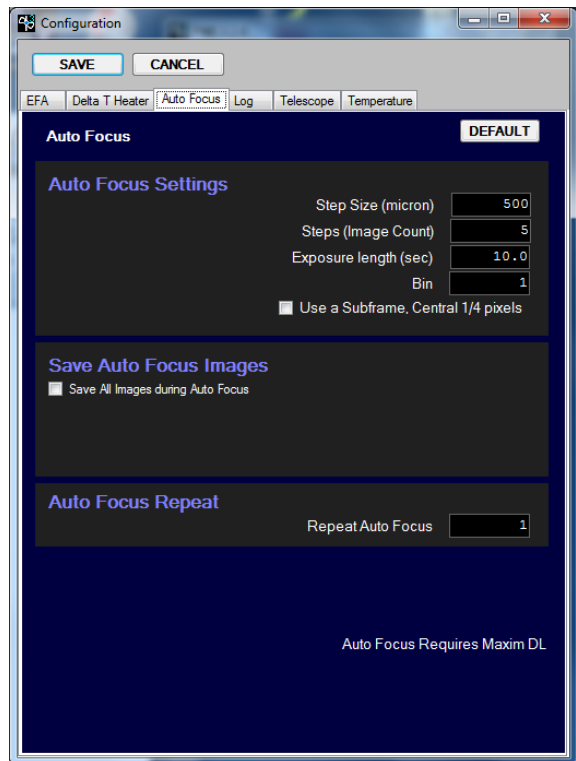
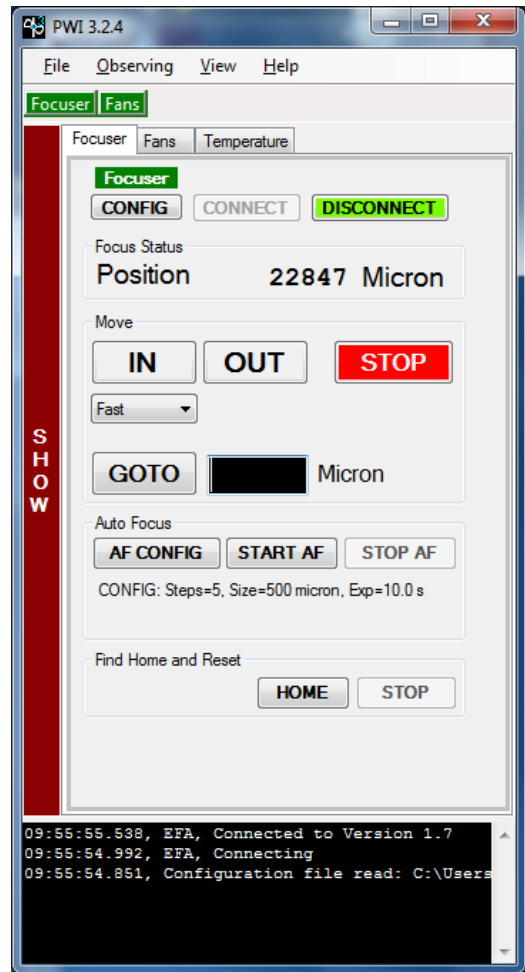
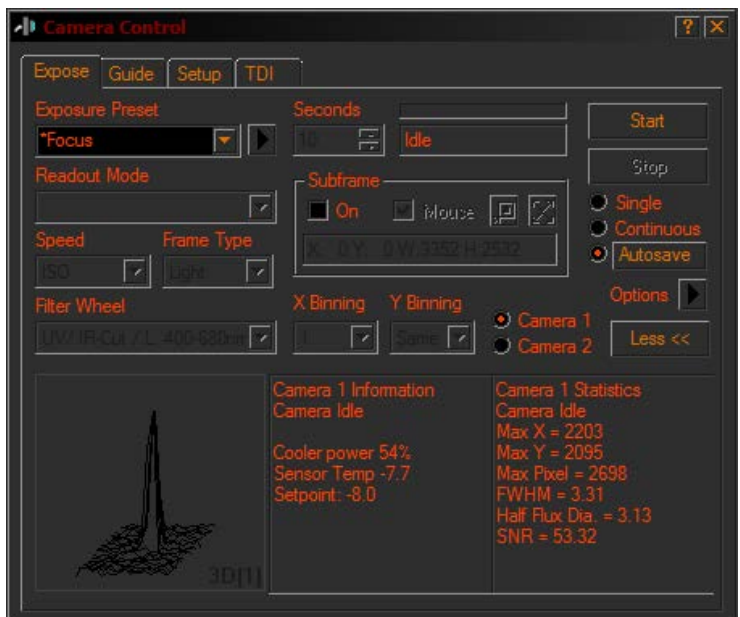
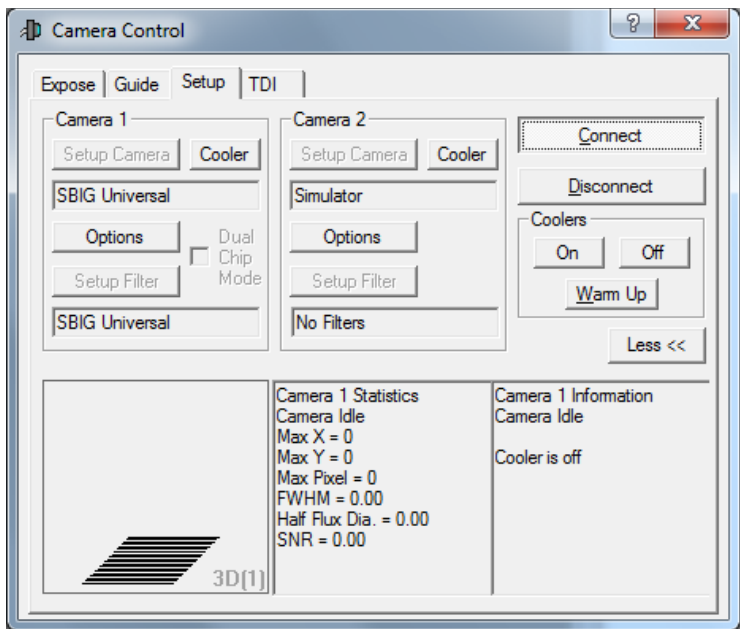
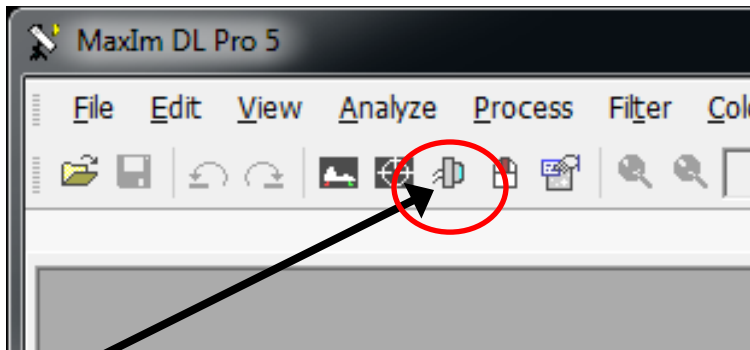
## 9 Camera Setup, Cooler Configuration, & Autofocus

This section describes how to initialize the CCD camera and perform the autofocus procedure in preparation for collecting imagery. The instructions in this section will not be useful unless the camera is being used. (Autofocus and camera coolers don't apply to the eyepiece.)

1. Using MaxImDL's Camera Control dialog (the icon to the left of Observatory icon):
  - (a) Select the Setup tab, choose the Connect button (connects camera #1, filter wheel, and guide camera #2)
  - (b) Select Coolers On button (toward mid-right in Setup tab)
  - (c) We typically set the camera coolers to -8C. The cooler setpoint can be changed by selecting the "Cooler" button in the "Camera 1" section of the dialog and changing the value in the resulting popup.  
\* Monitor the Cooler Power % in the "Camera 1 Information" box in this dialog. If the power remains high (over 75%) and the camera is clearly not going to reach the objective setpoint, please change the setpoint.
2. Find focus using the PWI application (focuser):
  - (a) Using MaxImDL's Camera Control Dialog, set the Filter Wheel to "No Filter" or "UV/IR cut"
  - (b) User PWI to move focuser to ~21500 (enter the value next to the "Goto" button, and press the button)
  - (c) Select "Start AF"
  - (d) Make sure STI telescope tracking is on, and the telescope can see through the dome
  - (e) Wait for the autofocus procedure to execute and complete (don't move excessively while this routine is being executed if you are on the platform!)  
The procedure will take 5 images at 10 seconds each, increasing the focuser 500 microns per step, and compute an optimal focus value. You can see the images the system is using if the MaxImDL window is being displayed.
    - i. If no solution is found and the images were poor, rerun the procedure starting at step (a).  
(It is possible that modification may be necessary in the "AF Config" dialog of PWI, although we have not needed to change these values.)
    - ii. If no solution is found but the images looked ok, move the focuser to a different starting position (not 21500) and return to step (c) to rerun the autofocus procedure.
  - (f) Wait for autofocus images to be taken (there are 5) and processed
  - (g) Use MaxImDL to take one more photo, just to make sure you concur with the autofocus setup: select the "Focus" preset, choose "Single" radio box, and press "Start" to take a photo.  
(Options: subframes off, autodark, 10 sec)
  - (h) Record the focus setting in the observing log
3. The PWI application can be minimized once focusing is completed

Focus can be set using the Celestron hand controller or the PWI application. Our experience is that focus is typically ~22500 when using the SBIG camera, and is ~16000 for the 31mm eyepiece.

These figures show the components and selections in MaxImDL and PWI for connecting a CCD camera and executing the PWI-based autofocus feature. Dialog labels are at the top of each image.





## 10 Manual Telescope Controls

Once power has been applied to the system, the telescope can be operated manually using hand controllers to move the OTA and focuser. These controls can be useful for visual observing (without a camera) and for initial setup or corrections during automated observing sessions.

Since proper tracking can only be achieved through computer-control initialization (Homing) of the telescope, a PC is still required for telescope initialization. Once the PC has been used to initialize the telescope and tracking is enabled, the hand controller can be used to point the OTA manually, and the mount will continue to track stellar (but not satellite) objects automatically.

### 10.1 Manual OTA Positioning and Control

1. Manual OTA positioning can be accomplished by using the small black hand controller with the white rubber keys. This controller will operate the OTA as long as the controller and mount are powered.
2. The directional keys will move the mount axes at three different speeds. The “rate” button cycles through “slew,” “jog,” and “guide” speeds, indicated by changing (red, yellow, and green) lights on the controller attached to the hand pad.

### 10.2 Manual Focuser Control

1. Manual focus can be achieved via the Celestron hand controller (with the orange backlit buttons) that attaches to the bezel on the back of the OTA.
2. Use the buttons labeled “Up” and “Down” (they also have number on them!) to cycle through menu options until the “focuser” menu is displayed, then select the “Enter” button.
3. The controller’s display shows the current focuser position (in mm), 0 is fully racked in.
4. The (up and down) Arrow keys will manually move the focuser when they are pressed.
5. Note that the focuser can also be controlled via the PWI computer application, which also shows a real-time display of the current focuser position.

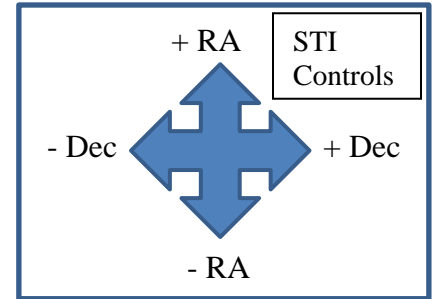
The Celestron hand controller used for manually focusing the system can also configure and control several other aspects of the OTA (such as cooling fan operation), but these additional controls are not commonly needed.

## 11 Tuning Pointing Accuracy

In most cases, the mount model will be fairly accurate. However, if the weight distribution on the lift is different, the mount model may need to be “corrected” (offset) for a given session. (The mount models are typically built with a single user on the lift standing at the keyboard.)

These instructions will make a one-time correction to the model for the duration of the current session. Once the software has been shut down, the offsets are lost. **(Performing a Home operation on the telescope will reload the mount model, discarding all sync and offset corrections.)**

1. Using TheSkyX Pro, select a bright star (Deneb, Altair, ...)
  - (a) left-click the star, right-click for a popup menu, select “Slew”,
  - (b) press dialog's OK button to confirm the slew
2. If an eyepiece is being used – repeat until the bright star is centered:
  - (a) Use the hand controller to move the telescope
  - (b) Pressing the Rate button between the cursor keys on the hand controller will cycle through fast (red light), medium (yellow light), and slow (green light) speeds
  - (c) Press the cursor keys (very briefly!) to move telescope in *very small increments*
3. If a camera is being used –
  - (a) Set exposure settings in MaxImDL's Camera Control dialog's Expose tab to “reasonable” values: i.e. 3-5 second exposure time, no subframe, and Option menu for *simple autodark* or *no dark frame subtraction*.
  - (b) Repeat until bright star is centered (using MaxImDL for camera control app & STI for telescope control):
    - i. Using MaxImDL's Camera Control dialog's Expose tab: select Start to take photo
    - ii. If bright star is not centered, use STI or the hand controller to move the telescope; Press the cursor keys or STI screen controls (very briefly!) to move telescope in *very small increments*. (Both the hand controller and STI can be configured to move the telescope at 3 different rates.)



Once the star is centered, use TheSkyX Pro to save model correction for this session:

1. NOTE: make sure the desired star is selected in TheSkyX Pro (red bulls-eye) before Sync!
2. From the Telescope tab at the left, use the Startup menu and select Synchronize
3. Press the “Sync” button on the dialog, and say “Yes” to confirm the sync.  
Be patient! This will take a few moments.

The correction has now been saved for this session. Additional corrections can be made if needed. (If everything seems “off” every time a new slew is performed, please tell an experienced operator so a new mount model can be generated. Building a new mount model won’t be accomplished and verified in “just a few minutes” of time, so you may need to continue your session at a later date if you need a newer or more accurate model.

[Note: An offset can be permanently saved by using the STI Home function to do “Find Transition Angle” operations for each axis. Since this impacts the telescope’s pointing position, *please do not* perform this operation unless you have made backups of the current mount model and know what you are doing!]



## 12 Loading TLEs for Satellite Tracking and Display

This section describes the process for loading Two Line Element (TLE) datasets for satellite tracking operations. Current TLEs can be downloaded from space-track.org from an internet-connected computer daily. The best format for TLE files is actually a *three* line record format, where the first line contains a text name for the satellite. Therefore, the three-line format should be downloaded from space-track.org.

The most current TLEs should be stored *on the desktop* in a folder named “TLE yyyyymmdd” and all previous TLE directories should be moved into the master “TLE” desktop folder. If you create a daily TLE folder, please follow this convention to avoid confusion and maintain consistency. You may add your own TLE files into the applicable daily folder as needed.

TheSkyX Pro does an excellent job of displaying the satellites. However, as of the end of FY2014, TheSkyX Pro reports errors and cannot actually use the PlaneWave to track moving satellites because of issues in the ASCOM implementation. (I am uncertain if the tracking problem is the fault of TheSkyX Pro or the ASCOM drivers the telescope uses; I’ve tried two simulated ASCOM drivers and two different commercial ASCOM drivers with the same results – no tracking capabilities. I suspect that TheSkyX Pro is finicky.)

To load TLEs into TheSkyX Pro:

1. Select menu item: Input → Satellites
2. Select “Remove All” to clear satellites
3. Select “Import from File” and open desired TLE file in the “Desktop\TLE yyyyymmdd\” folder
4. Change any desired display characteristics, and close the Satellites dialog

The mount manufacturer’s driver, SiTechExe, has satellite tracking built into the driver. (PlaneWave’s STI driver code is forked from SiTechExe, but STI does not include satellite tracking.) SiTechExe has a variety of helpful controls to assist a user desiring to track moving satellites.

\* Note that either SiTechExe or STI can be used to control the PlaneWave, but not both at the same time. To use SiTechExe instead of STI:

1. Use STI to park the telescope
2. In the ASCOM application, tell the Poth Hub to disconnect from STI, then select the SiTechExe controller, and tell Poth to Connect
3. Use the SiTechExe application to Home the telescope

This process can be accomplished with the other system component running, because they are connected to the Poth Hub “telescope,” which merely passes control to an alternative ASCOM application.

To load TLEs into SiTechExe:

1. Select the Satellite Control tab
2. Choose the desired TLE file from the “Desktop\TLE yyyyymmdd\” folder
3. The Satellite Control dialog allows the user to update the list of satellites currently visible. SiTechExe has a decent Help guide built into the system, describing the various controls available to the user.

## 13 Dome Control and Dome Alignment

This section describes the Dome Control application.

The Dome control GUI is only able to operate after the dome control hardware has been powered on and The Sky X Pro is running. *A telescope does not have to be connected in order to initialize the Dome GUI*, but some functionality (such as synchronously tracking the dome and telescope) will not be enabled unless a telescope is connected to The Sky.

1. Select the Dome Control Interface icon to begin the Dome GUI.

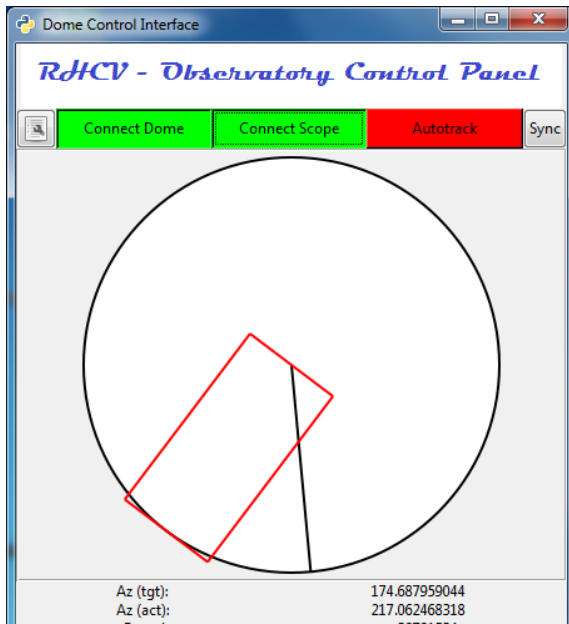


Figure 13-1: Observatory Control connected

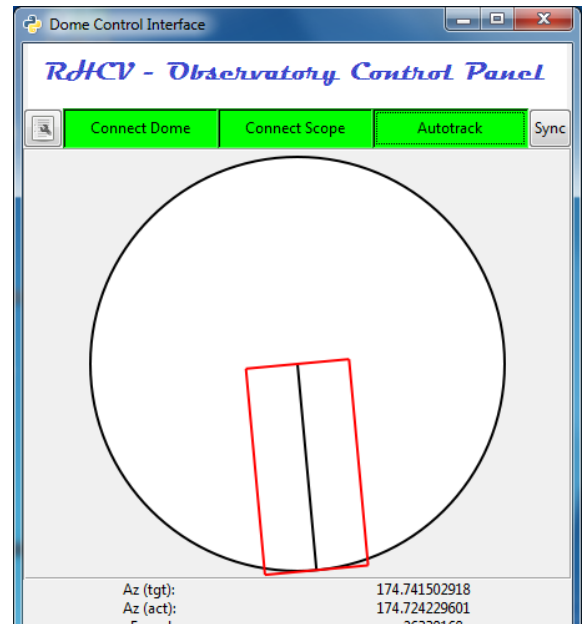


Figure 13-2: Observatory Control in automatic mode

2. Select “Connect Dome” and “Connect Scope” buttons at the top of the GUI. They will turn green when connected.
3. Use the buttons at the bottom of the Dome GUI to rotate the dome, pointing the shutter in the same direction the telescope optical tube is pointing. Once the dome and optical tube are aligned, press the “Sync” button at the top right of the Dome GUI. This will synchronize the encoders so the dome and The Sky will remain aligned. The Sync button can be pressed at any time to re-align the dome and The Sky, if needed.
4. Once alignment has occurred, select the “Autotrack” button to automate the dome rotation. This feature will synchronize dome motion with telescope motion. Autotrack will be canceled if the dome is moved manually using the buttons at the bottom of the Dome GUI, but can be reactivated by selecting “Autotrack” again as desired.

The dome may require additional positioning and synchronization adjustments during an observing session to maintain accuracy.

## 14 Tips for Collecting CCD Camera Data

This section contains tips for CCD imaging. MaxImDL has extensive build-in help and tutorials; users are referred to these tutorials, which provide an excellent introduction to CCD imaging and the capabilities of MaxImDL.

These instructions refer to selections that can be made from the Expose tab on the Camera Control dialog. Those familiar with CCD imaging will already know what settings they will want to use in various situation. For the rest of us:

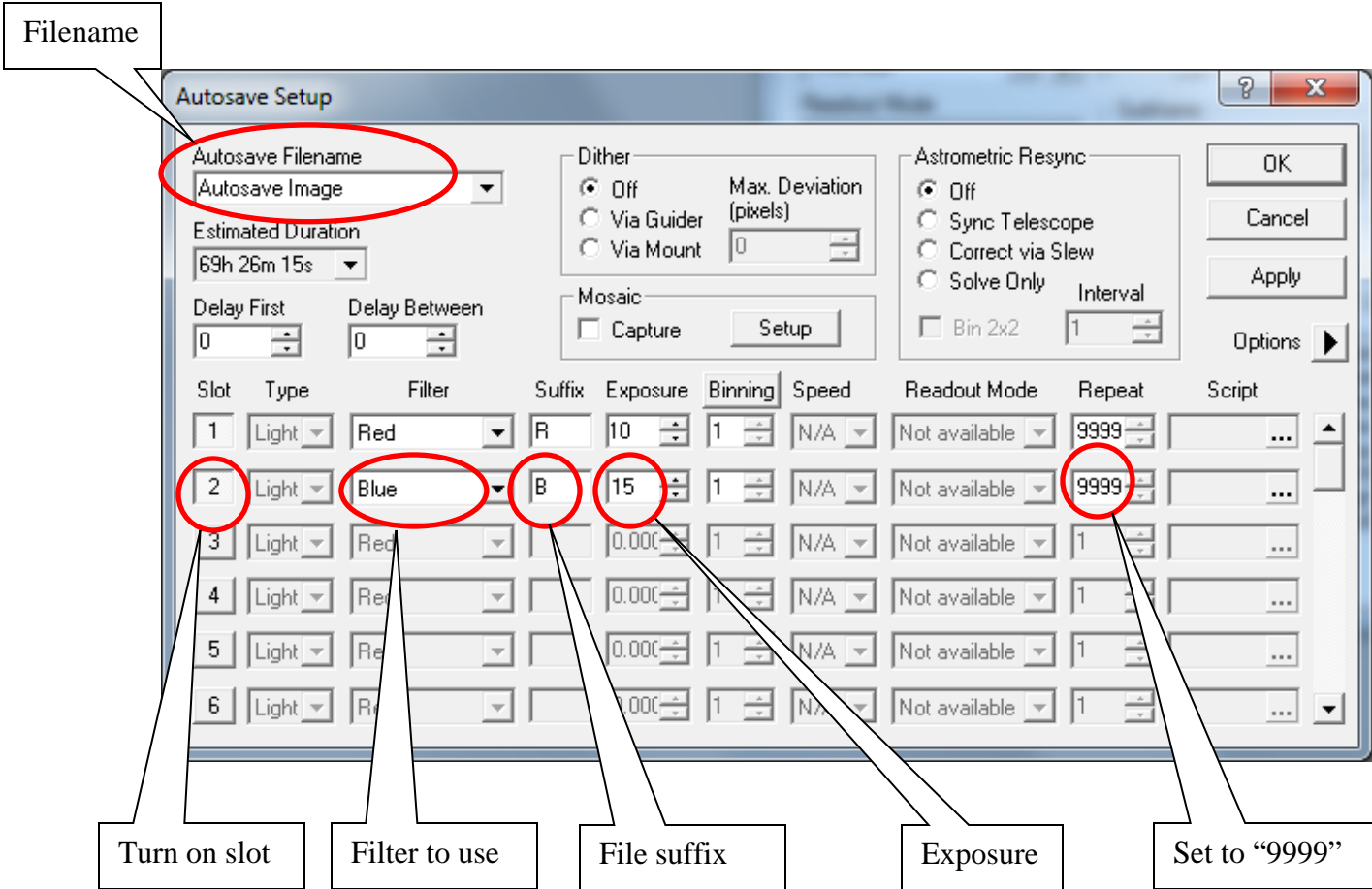
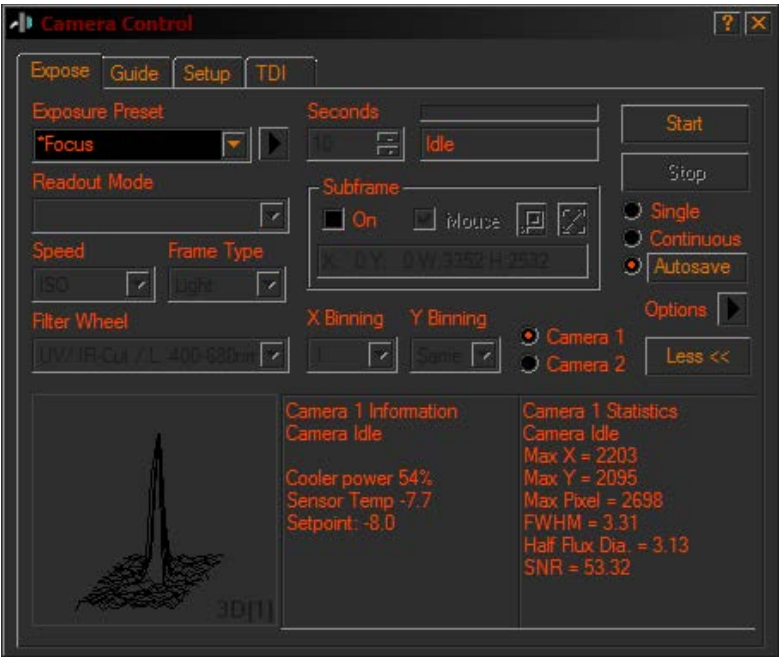
1. Exposure preset – The Preset saves any changes you might make in this dialog. For standalone data collection efforts, just use the “Focus” preset. If you create your own preset (from the pulldown), your Autosave scripts and other modifications will be saved to your preset.
2. Seconds – Camera exposure time
3. Subframe – generally not checked; subframes record only a portion of the CCD image
4. Binning – we often use binning of 1 for X and Y. Binning combines CCD pixels. Setting depends on your own needs.
5. Single/Continuous/Autosave – Single takes and displays one photo. Continuous will cycle the camera and take photos continuously. Autosave will run the script defined by the Autosave button. Images in Single and Continuous modes may or may not be saved automatically.
6. Options is a pulldown menu with several options. The top few options have to do with dark frame subtraction: No calibration, Autodark, or Full Calibration. Autodark is easiest, but may not suit your specific needs.
7. The Options pulldown also contains a setting to control where (to which folder) images are saved.
8. The three (3) info boxes at the bottom of the dialog are configure to report image and camera statistics.

When the Autosave button is pressed, a script can be generated to control camera filters, exposure, etc. Each step is executed in Slot sequence, then the script is restarted from Slot 1. This gives a great deal of control for automated for image collection. The Autosave Setup figure on the following page graphically shows some typical settings.

1. Set the Autosave Filename to the base filename you’d like to use. (Remember to set the destination folder in the Options menu of the Camera Control dialog.)
2. Select each Slot for a setting you’d like to control
3. Choose the filter to apply, set a filename suffix, exposure, and binning.
4. Set Repeat to 9999. (This will run a very long time. Just use “Stop” in Camera Control to abort the script.)
5. Choose “Ok” to save the script. Select Autosave in Camera Control, and Start to begin execution.
6. The script will save file0000, file0001, file0002, .... until the script is halted, with each fileXXXX being repeated with a suffix for the corresponding slot. If the script is restarted, it will begin with the next available filename.

MaxImDL can also take dark frames and bias frames, in addition to light frames.

These figures represent MaxImDL's Camera Control Dialog, concentrating on the Expose tab and typical Autosave Setup subdialog settings.



## 15 System Shutdown Procedures

There are two types of shutdown procedures. The “Brief Shutdown” procedure is a fast and safe way to put the system into a safe mode until it can be fully shut down the following day by an operator. The “Complete Shutdown”

**Brief Shutdown:      result – turn off camera coolers; park telescope; close dome**

1. Using MaxImDL (Camera Control dialog):
  - (a) Camera Control dialog, Expose tab: select “Stop” from the halt any pending data collection
  - (b) Camera Control dialog, Setup tab: select “Cooler Off” and select “Disconnect”; Close the dialog
2. If the platform is raised and you are not on it already:
  - (a) Lower the platform until you are comfortable stepping onto the platform;
  - (b) Use the yellow pendant on the hydraulic compressor
  - (c) Don't completely lower the platform using the pendant, this will jar the telescope!
3. Using STI, press the Stop button in the center of the window to turn off telescope tracking
4. Use the telescope hand controller to lower the OTA to a horizontal orientation
5. Connect the remote monitor USB plug (the cable with the orange post-it on the plug)
6. Get onto the lift, and raise the lift completely
7. Secure the Dome:
  - (a) Use the Dome Control application to rotate the dome shutter for access
  - (b) Close the shutters manually (be forceful)
  - (c) IMPORTANT: insert the pin to secure the shutters
8. Gently fully lower the platform – Use the green release lever to control the descent rate
9. Unplug the remote USB monitor (the cable with the orange post-it on the plug)
10. Turn off both wall power boxes; Leave PC logged in, a screen saver will start later
11. Lock catwalk door and return the key to its storage hook

**Complete Shutdown (C): result – everything will be powered down**

1. Using MaxImDL (camera control):
  - (a) Camera Control dialog, Expose tab: select “Stop” from the halt any pending data collection
  - (b) Camera Control dialog, Setup tab: select “Cooler Off” and select “Disconnect”; Close the dialog
  - (c) Observatory Control dialog –Select “Disconnect All” and close the dialog
  - (d) Close the MaxImDL application
2. Using PWI (focuser application): Close the PWI application (it will disconnect automatically)
3. Using the Dome Controller application: de-select “Connect Telescope”
4. Using TheSkyX Pro (GUI application):
  - (a) Select the Telescope tab at the left
  - (b) Select the Shutdown menu, and choose “Disconnect Telescope”
  - (c) Close TheSkyX Pro application
5. If the platform is raised and you are not on it already:
  - (a) Lower the platform until you are comfortable stepping onto the platform;
  - (b) Use the yellow pendant on the hydraulic compressor
  - (c) Don't completely lower the platform using the pendant, this will jar the telescope!
6. Using STI (telescope controller):
  - (a) Select Park from the Command pulldown menu at the center of the window
  - (b) WATCH the park operation and be prepared to stop the scope by removing power if it does not stop!  
*It IS possible to crash the OTA into the mount!*
  - (c) In order: close the ASCOM application, and close the STI application, if they are running
7. Connect the remote monitor USB plug on the lift
8. Get onto the lift, and raise it completely
9. Secure the Dome:
  - (a) Use the Dome Control application to rotate the dome shutter for access
  - (b) Close the shutters manually (be forceful)
  - (c) IMPORTANT: insert the pin to secure the shutters
  - (d) De-select “Connect Dome”
  - (e) Close the Dome Control application
10. Gently fully lower the platform; Use the green release lever to control the descent rate
11. Unplug the remote USB monitor
12. Turn off both wall-mounted power disconnect boxes and lock the Lift Power box
13. Do not turn off the PC; you can leave it logged in, a screen saver will start later
14. Lock catwalk door and return the key to its storage hook

Figures depicting selected application shutdown functions are included here:

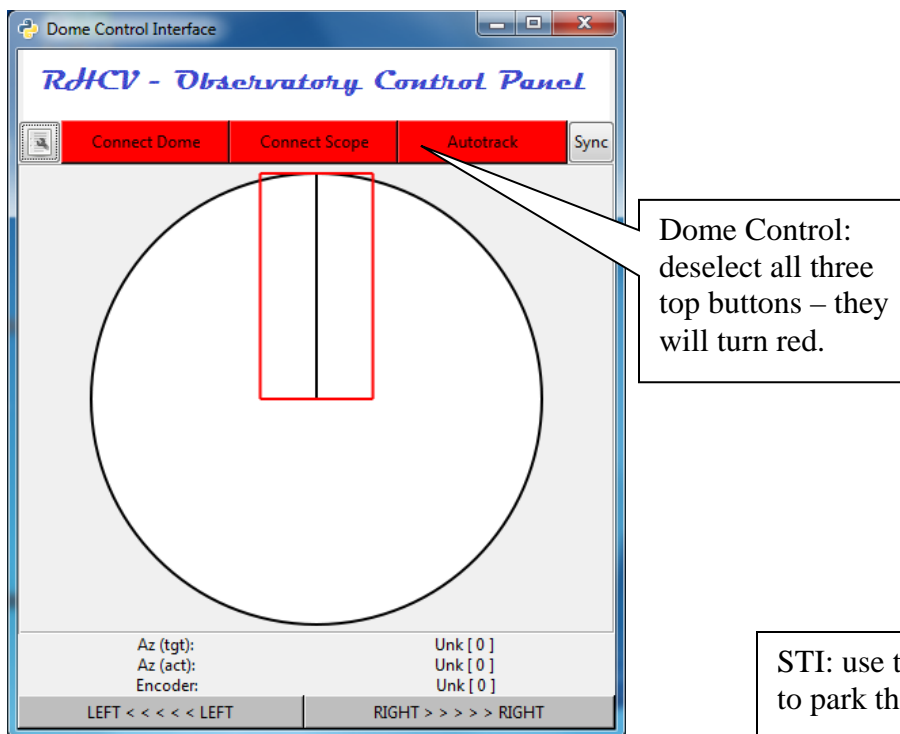


Figure 15-1: Dome GUI disconnected

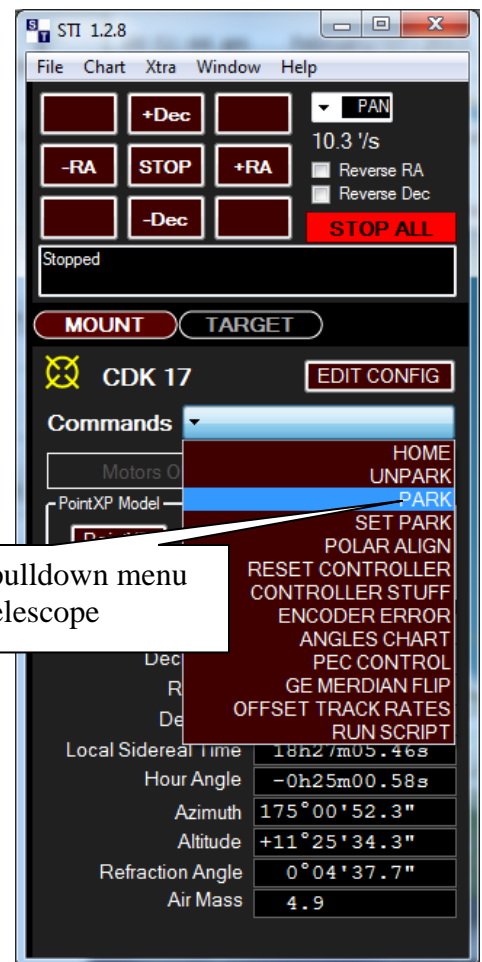


Figure 15-2: STI -- Parking the Telescope

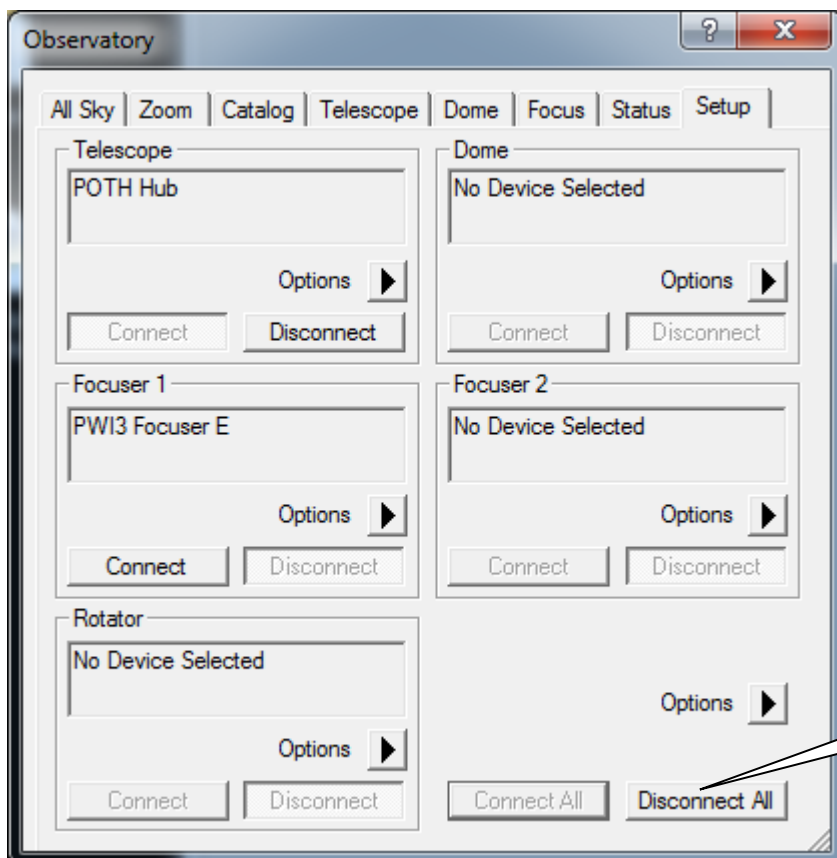


Figure 15-3: MaxImDL Observatory Control window -- Disconnect All



## 16 Building a Mount Model (Advanced)

The process that generates a telescope mount model for the RHCV PlaneWave 17" telescope follows the steps outlined in Section 5.1 (pp. 74—89) of the Sidereal Technology “Operations Manual” Draft 1.1, revised October 20, 2009.

These example images are associated with the generation of a mount model.

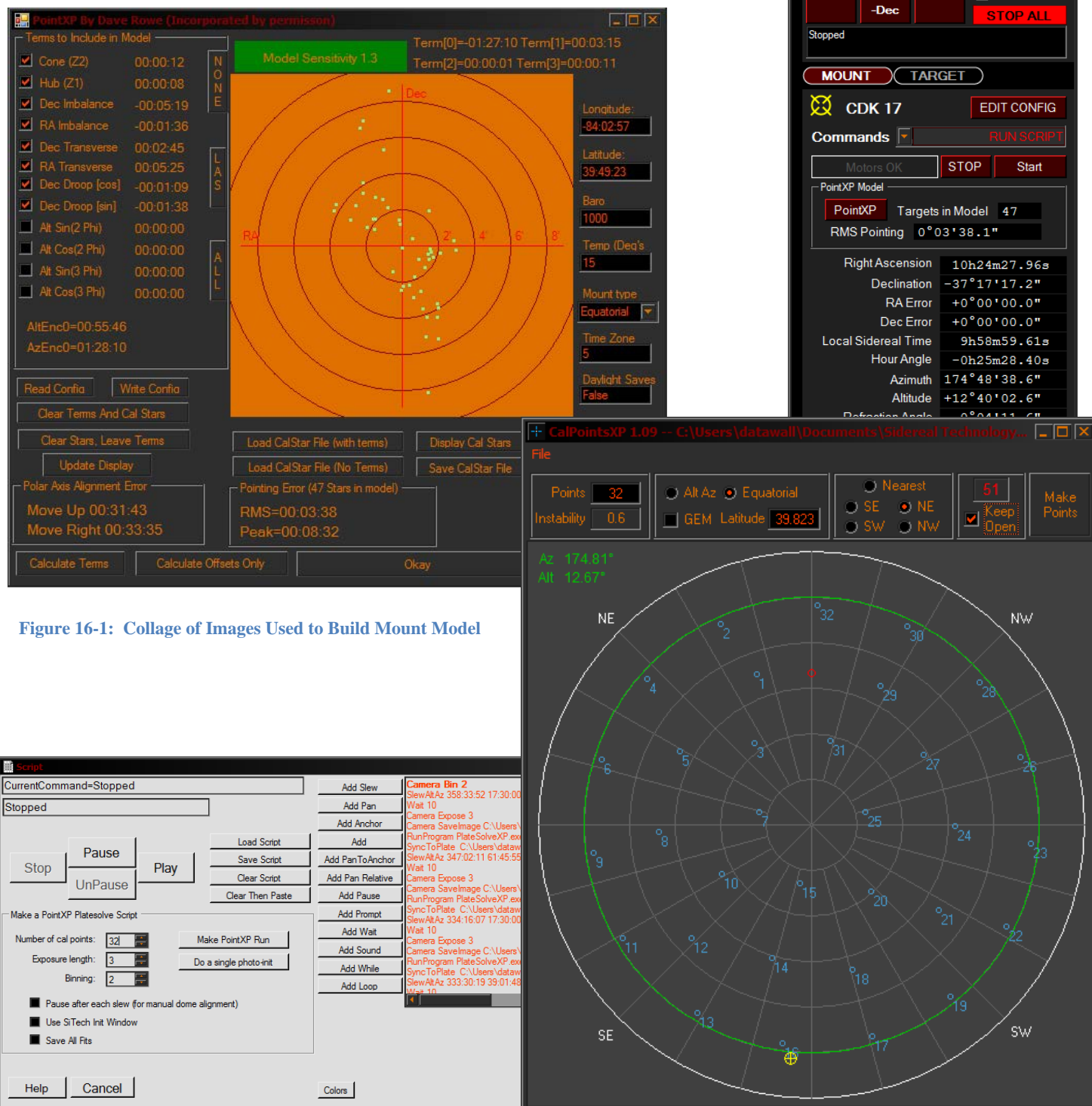


Figure 16-1: Collage of Images Used to Build Mount Model



## 17 Attendant Training – topics to cover

This short document is intended to be a list of topics an Operator must cover to introduce and qualify an individual as a telescope Attendant for studies that do not involve slewing the telescope. This section is not intended to be a complete “training guide” that can be read and fully understood by inexperienced personnel.

Training for Attendant personnel can be accomplished in two (2) parts: daytime physical component training, and nighttime software operations. Although the software operations training can also be performed during the day, it is best to cover the software topics in the evening when the camera images can be used to demonstrate the relevant procedures.

### General comments:

An Attendant should plan to arrive for their shift at a time that allows at least 30 minutes of overlap between Operator and Attendant; this will allow for a good operational handoff from the Operator to the Attendant.

### Attendant Daytime Physical Component Training (30 minutes)

The intent of this portion of the training is to familiarize the attendant with the physical components of the observatory system that will be used during system shutdown and (possibly) under limited circumstances during data collection.

- Introduce telescope system – reflecting telescope, truss design; pier/mount/optical tube assembly (OTA). Special coatings to allow collection from 250—2500nm (visual is 400—700).
- Point out complete instruction document, and Operator contact information.
- Energize (and point out) wall power disconnect switches.
- Point out Control PC.
- Start Dome Control program and STI
- Show remote monitor USB plug.
- Ride lift to top, new Attendant control motion. Lift operations safety brief.
- Show telescope LED light, clipped near monitor.
- Point out all dome emergency stop switches.
- Dome shutter operations (Op: move, open & move dome; trainee: move & close dome)
- Dome shutter pin storage and installation
- Ride lift to bottom; use lever to carefully lower platform.
- Point out friction dovetails. (Op: home telescope)
- Park OTA using hand controller (show controller, slew speeds; trainee: “park” scope)
- Show OTA emergency stops: controller on pier; wall power; software stop
- Log sheet on clip board. Other materials and phone numbers on cork board.
- Walk through complete shutdown procedure: when collection is finished ...
  - Lower lift using yellow pendant (not all of the way to floor)
  - Level OTA
  - Connect external monitor USB
  - Ride lift to the top, rotate and close dome, lower lift; disconnect external monitor USB
  - Turn off camera coolers and disconnect camera
  - Kill power at the wall switches

## Attendant Software Operations (Night Time) Training (30 minutes)

The intent of this portion of the training is to demonstrate the operation of key software components that might be used by the Attendant in order to prevent unnecessary degradation of the quality of the data collected by the system.

- Show observing schedule (& primary/secondary attendants), contact info
- Log sheet location and information
- Check weather regularly (show access key and where to look for weather)
  - Note: Emergency shutdown procedures are the same as standard Brief procedures
- Walk through shut down procedures
- Keep lab door open during operations, close when leaving
- PC login
- Only use Control PC for telescope operations
- Show PWI (focuser) software
- Show MaxImDL Camera Control for data collection; Start/Stop and Autosave script settings
- Show MaxImDL “target” icon and where to look/what to expect for max pixel values
- Text or email sitrep to designated Operator: observing times, settings, shutdown reason, max observed pixel
- Call designated Operator for any reason if the system doesn’t appear to be cooperating

## 18 Conclusion

This document highlights the major hardware components of the automated dome control system, and outlines the procedure necessary for calibrating the system for operational use with the RHCV telescope. The automated system is intended to be used as an integrated part of the RHCV observatory system.

## 19 References

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- Shattuck, Judson LaMoure, III; Schmidt, Vincent A.; Campbell, Pawlos; Kern, Jacob. Design, Operation, and Maintenance of the Automated Rotation Control System for the 2.5-Meter Observe-Dome. February 2013. Approved for public release: AFRL-RH-WP-TP-2013-0017.

# Appendix A: Observatory System Executive Startup and Shutdown Procedures

## A.1 Executive Startup Procedures

1. Power up all hardware – dome controller, scope power, hydraulic lift, etc.
2. Start MaxImDL. Select the Observatory tool, and choose the “Connect All” button. The STI (mount model controller) and PWI (focuser) programs will start. PWI can be minimized
3. In the STI window, select “Home” from the Commands menu in the center of the display Press the “Initialize Scope Using Homing Switches” button at the bottom of the “Homing Operations Window.” Wait until both axes show a status of “idle,” then press OK. (The mount model is now loaded)
4. Press the Start button on STI (in the center of the screen, beneath the Commands menu) to start tracking mode. STI can be minimized if desired
5. Start The Sky X Pro, and choose “Connect Telescope” from the Start menu in the Telescope tab
6. Start the Dome Control Interface; Select the “Connect Dome” and “Connect Scope” buttons to begin dome communications and control
7. Use the grey arrow buttons on the bottom of the Dome GUI to rotate the dome so the shutter is pointed the same direction as the telescope optical tube. Press “Sync” on the Dome GUI
8. Press “Autotrack” on the Dome GUI to automate dome tracking
9. The pointing system initialization is now complete
10. It may be necessary to slightly adjust the mount model to improve pointing accuracy: use STI to nudge the telescope until the selected bright star is centered in the eyepiece or camera, then select “Synchronize” in the Startup menu of the Telescope tab in The Sky X Pro, then press the “Sync” button in the resulting dialog. This adjustment will be valid for until the software is shut down or the mount model is reloaded.

**NOTE: DO NOT EVER** leave the telescope unattended in tracking mode! You can press the “Stop” button on the STI GUI to halt tracking, or Park the scope using STI. Mount controller power can be left on if necessary. A telescope in tracking mode will move 15 degrees per hour!

**NOTE: DO NOT EVER** leave the telescope oriented unattended in a vertical or near-vertical configuration of the optical tube (“pointing up”), whether or not power is applied to the controller.

## A.2 Executive Shutdown Procedures

1. Disable dome control from the Dome Control Interface by de-selecting the Autotrack, Connect Scope, & Connect Dome buttons. Close the Dome GUI using the red “X” at the upper right side of the window
2. Using MaxImDL’s Observatory tool, select “Disconnect All,” then close PWI and MaxImDL.
3. Using MaxImDL’s Camera tool, turn the cooler off and disconnect all cameras
4. Close the MaxImDL and PWI (focuser) applications
5. Close The Sky X Pro application (you may need to disconnect the telescope from The Sky)
6. Use STI’s command menu to Park the telescope, then close STI once it is parked
7. Power off all hardware. Please leave the control PC running and logged in

## Appendix B: Geostationary Satellite Data Collection – Detailed Summary of Telescope System Startup and Shutdown Procedures

**!!! CHECK WEATHER BEFORE YOU BEGIN & REGULARLY DURING COLLECTION !!!**

### STARTUP (Operator)

1. Ensure the scope & pump power disconnect switches are off, & unplug external monitor USB
2. Reboot the Control PC and log in
3. Energize the scope and pump power disconnect switches after the PC has booted
4. Turn on air compressor
5. Plug in the external monitor USB
6. Make sure the Dome Controller power is on (wall switch is near gray box)
7. Visually inspect cabling to ensure OTA and camera cables can move freely
8. If the OTA is not in its park position, use the hand controller to approximately level the OTA
9. Start the MaxImDL application using the desktop shortcut
  - (a) Start Observatory dialog,
  - (b) Select “Connect All” to connect to STI (telescope control) and PWI (focuser)
  - (c) Close the Observatory dialog
10. Start TheSkyX Pro application using the desktop shortcut
  - (a) Select the Telescope tab at the left of the screen,
  - (b) Select “Look Up” icon on ribbon menu at the top of the application screen
11. Ride the lift to the top (adhere to posted Observatory Safety Tips)
12. Check dome tire air pressure, inflate to 50 PSI if required.
13. Start the Dome Control application
  - (a) Select “Connect Dome” button at the top of the application screen
  - (b) Rotate dome using the buttons at the bottom of the application until the shutter is accessible
14. Open the dome shutter (manually) by removing the pin and pulling the handles apart
  - (a) Store the pin in the dome apron
15. Using the Dome Control application:

Use the buttons at the bottom to center the dome shutter directly in front of the OTA
16. Ride the lift down; do not lower the lift completely in order to avoid jarring the telescope
17. Turn off air compressor
18. Using STI (the telescope control application):
  - (a) Select “Home” from the Command pulldown in the center of the screen
  - (b) Select “Initialize Scope Using Homing Switches” in “Homing Operations Window” dialog
  - (c) Wait for initialization to complete (“Idle” status on both axes), and press dialog’s “OK”
  - (d) Select “Start” in the center of the STI screen to begin telescope tracking.
19. Disconnect the remote monitor USB
20. Using TheSkyX Pro: select “Connect Telescope” from Startup menu in Telescope tab
21. Using the Dome Control application: Select “Connect Scope”; Select “Sync”; Select “Autotrack”

(NOTE: The dome may require additional positioning adjustments to ensure accuracy.)
22. Use the yellow hand controller to raise the lift to the top (with no person on the lift)

## FILE, CAMERA, & MODEL INITIALIZATION FOR DATA COLLECTION (Operator)

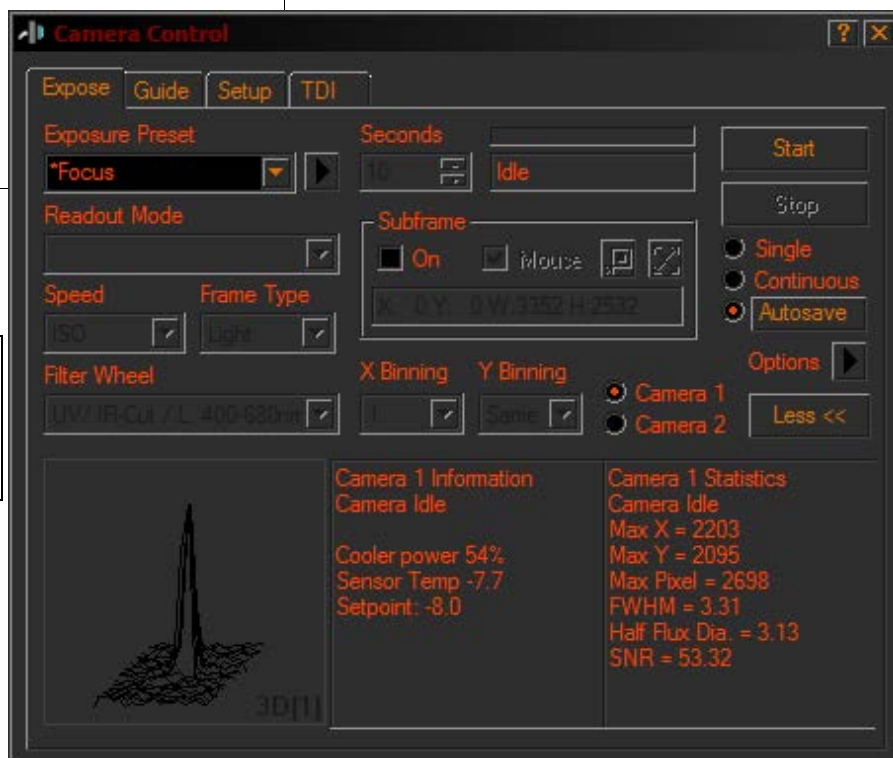
### Data files, Load TLEs, and Camera Init. & Focus

4. Using File Manager:
  - (a) Ensure any of last night's \*.FIT files in Desktop\Images are moved to an appropriate subdirectory.
  - (b) Create a directory for tonight's data files:  
**Desktop\Images\YYYYMMDD NAME**
5. Using TheSkyX Pro:
  - (a) Select menu item: Input → Satellites
  - (b) Select "Remove All" to clear satellites
  - (c) Select "Import from File" and open file Desktop\TLE YYYYMMDD\geo.txt
  - (d) Close the Satellites dialog
6. Using MaxImDL's Camera Control dialog (icon to the left of Observatory icon):
  - (a) Setup tab, select Connect button (connects camera #1, filter wheel, and guide camera #2)
  - (b) Select Coolers On button (toward mid-right in Setup tab)
7. Set focus using the PWI application (focuser):
  - (a) Select "Start AF"
  - (b) Wait for autofocus images to be taken (there are 5) and processed
  - (c) It is generally a good idea to use MaxImDL to take one more photo, just to make sure you concur with the autofocus setup: select the "Focus" preset & set values to use.
  - (d) Minimize PWI

### Mount Model Correction

4. Using TheSkyX Pro, select a bright star (Deneb, Altair, etc.)
  - (a) left-click the star, right-click for a popup menu, select "Slew",
  - (b) press dialog's OK button to confirm the slew
5. Set exposure settings in MaxImDL's Camera Control dialog's Expose tab to reasonable values
6. Repeat as required: (using MaxImDL for camera control app & STI for telescope control)
  - (a) Using MaxImDL's Camera Control dialog's Expose tab: select Start to take photo
  - (b) Proceed to (d) if the bright star is centered
  - (c) If bright star is not centered, use STI to move the telescope:
    - i. Set Rate to Pan (med) or Slew (fast)
    - ii. Tap the cursor keys (very briefly!) to move telescope in *very small increments*
7. Use TheSkyX Pro to save the model correction for this session:
  - (a) NOTE: make sure the desired star is selected in TheSkyX Pro (red bulls-eye) before Sync!
  - (b) From the Telescope tab at the left, use the Startup menu and select Synchronize
  - (c) Press the "Sync" button on the dialog, and say "Yes" to confirm the sync.
  - (d) Be patient! This can take a few moments.

Figure B-1:  
Camera Control  
Dialog



## CALIBRATION FOR DATA COLLECTION (Operator)

Actual collection of satellite data should occur between 9pm and 5am (nominally). PM's typically want about 5-10% of our time each night for three (3) of the calibration settings to characterize the night's observations. That amounts to about 30 minutes total (10 minutes per setting). If an operator begins setup near 8pm and is running calibration by 8:30pm, data collection can start shortly after 9pm.

**Calibration stars:** – Collect 10 minutes of data on each set of calibration stars: (i.e. SA109 & SA1105)

1. Use TheSkyX Pro to slew to the calibration star
2. Use MaxImDL's Expose tab on the Camera Control dialog
  - a. Take a single photo, 20 seconds or so, binning 2x2, using the UV/IR Cut filter, Subframe off
  - b. Compare the image to confirm the selected setting is in the field of view; adjust using STI if necessary. (Note: telescope will be in tracking mode for these operations)
  - c. Take a single photo using the Red filter (exposure @ 25 seconds)
  - d. Adjust exposure time and repeat until max pixel for Red is ~10K
  - e. Take a single photo using the Blue filter (exposure @ 30 seconds)
  - f. Adjust exposure time and repeat until max pixel for Blue is ~10K
  - g. Set Autosave options (dialog will appear) to capture Red (suffix=R) and Blue (suffix=B), exposure as discovered in previous steps for respective filters, Binning 2, Repeat 9999. Select "Ok" in dialog.
  - h. Press Start in the Camera Control dialog, and allow the system to take 10 minutes of data.

### Set up for Satellites:

1. Determine which satellite(s) will be selected for collection based on the night's observing schedule. Ensure the satellite is within view (over the horizon).
2. Using TheSkyX Pro:
  - a. Slew to the desired Setting.
  - b. Zoom and reposition until scope (yellow bulls-eye) is in the "camera view" purple square
  - c. Play the "geo satellite game" to center the scope between both satellites for the Setting
    - i. Be ready to turn tracking off ("Stop" in STI)
    - ii. Remember, using STI's RA/DEC buttons turns tracking back on!
    - iii. You will be moving between TheSkyX Pro, STI, and MaxImDL frequently.
    - iv. Use the Dome Control application to turn dome Autotracking off
3. Use MaxImDL's Expose tab on the Camera Control dialog
  - a. Take a single photo, 20 seconds or so, binning 2x2, using the UV/IR Cut filter, Subframe off
  - b. Examine the image to confirm both satellites of the selected Setting are in the field of view; adjust using STI if necessary. (Telescope tracking must be off for these operations)
  - c. Image should contain single dots (satellites) in good focus, "star trail" streaks are possible
  - d. Take a single photo using the Red filter (exposure @ 5 seconds)
  - e. Adjust exposure time and repeat until max pixel for Red is in the range (2000—10000)
    - i. Use the Information dialog (icon to the left of the toolbar's Camera Control icon)
    - ii. The Area mode (selectable from the pulldown menu) allows a box to be drawn around an area of an image.
    - iii. After boxing the satellite, use the max pixel value in this dialog to guide exposure
  - f. Take a single photo using the Blue filter (exposure @ 8 seconds)
  - g. Adjust exposure and repeat until max pixel for Blue is the range (2000—10000)
  - h. Set Autosave options (dialog will appear) to capture Red (suffix=R) and Blue (suffix=B), exposure as discovered in previous steps for respective filters, Binning 2, Repeat 9999. Select "Ok" in dialog.
  - i. Press Start in the Camera Control dialog
  - j. At this point, the system is in steady-state for the evening.



## COLLECTING DATA FOR GEO SATELLITES (Attendant)

### Steady-State operation (Attendant)

1. CHECK WEATHER REGULARLY! Immediately execute Shutdown Procedure if the weather becomes uncooperative (excessively overcast or includes precipitation in any form)
2. During the data collection:
  - (a) Imagery will be captured and saved continuously, & displayed on the monitor in real time
  - (b) The telescope will change filters automatically
3. If satellites move out of the image, contact Vince (or designated operator) to make adjustments
4. Check the max pixel values of satellites using MaxImDL's Information dialog (icon to the left of the Camera Control icon in the toolbar):
  - (a) Use the Area mode (selectable from the pulldown menu) to draw a box around each satellite
  - (b) The status of the selected area is displayed in real time in the dialog
  - (c) The maximum pixel value should remain in the range (2000, 20000); 8000-10000 is ideal.
5. Adjust Exposure as needed to maintain maximum pixel values
  - (a) Press Stop in the Camera Control dialog's Expose tab to stop data collection
  - (b) Press the Autosave button & change the desired Exposure value in the Autosave Setup dialog
  - (c) Press OK to save the value and dismiss the dialog.
  - (d) Press Start in the Camera Control dialog's Expose tab to continue collecting imagery
6. Select and use a Shutdown Procedure when the shift is over
7. Fill in the log sheet on the clipboard
8. Make sure the catwalk door is locked before leaving for the evening
9. Send a short email to the designated Operator or PM, to include:  
Setting, start and stop time of data collection, any comments. Please include reason why data collection was halted (end of shift, overcast skies, etc.)
10. Please do not use the telescope Control PC for anything except for data collection and telescope control!



Figure B-2: Camera's Autosave Setup Dialog

## **SYSTEM SHUTDOWN (Attendant: Select either Brief or Complete Shutdown method)**

### **Brief Shutdown (B): turn off camera coolers; park telescope; close dome**

1. Using MaxImDL (Camera Control dialog):
  - (a) Select “Stop” from the Expose tab to halt data collection.
  - (b) Select the Setup tab. Select “Cooler Off” and select “Disconnect” and close the dialog
2. Lower the platform until you would be comfortable stepping onto the platform;
  - (a) use the yellow pendant on the hydraulic compressor
  - (b) Don't completely lower the platform using the pendant, this will jar the telescope!
3. Use the telescope hand controller to lower the OTA to a horizontal orientation
4. Connect the remote monitor USB plug (the cable with the orange post-it on the plug)
5. Get onto the lift, and raise the lift completely
6. Secure the Dome:
  - (a) Use the Dome Control application to rotate the dome shutter for access
  - (b) Close the shutters manually (be forceful)
  - (c) IMPORTANT: insert the pin to secure the shutters
7. Gently fully lower the platform – Use the green release lever to control the descent rate
8. Unplug the remote USB monitor (the cable with the orange post-it on the plug)
9. Turn off both wall power boxes; Leave PC logged in.
10. Lock catwalk door

### **Complete Shutdown (C): everything will be powered down**

1. Using MaxImDL (camera control):
  - (a) Select “Stop” from the Expose tab to halt data collection.
  - (b) Select the Setup tab. Select “Cooler Off” and select “Disconnect” and close the dialog
  - (c) Observatory Control dialog –Select “Disconnect All”
  - (d) Close the application
2. Using PWI (focuser): Close the application (it will disconnect automatically)
3. Use the Dome Controller application and de-select “Connect Telescope”
4. TheSkyX Pro:
  - (a) Select the Telescope tab at the left
  - (b) Select the Shutdown menu, and choose “Disconnect Telescope”
  - (c) Close the application
5. Lower the platform until you are comfortable stepping onto the platform;
  - (a) Use the yellow pendant on the hydraulic compressor
  - (b) Don't completely lower the platform using the pendant, this will jar the telescope!
6. Using STI (telescope controller):
  - (a) Select Park from the Command pulldown menu at the center of the window
  - (b) **WATCH** the park operation and be prepared to stop the scope by removing power if it does not stop! It IS possible to run the OTA into the mount!
  - (c) In order: close the ASCOM application, and close the STI application, if they are running.
7. Connect the remote monitor USB plug
8. Get onto the lift, and raise it completely
9. Secure the Dome:
  - (a) Use the Dome Control application to rotate the dome shutter for access
  - (b) Close the shutters manually (be forceful); IMPORTANT: insert the pin to secure the shutters
  - (c) De-select “Connect Dome”
  - (d) Close the application
10. Gently fully lower the platform; Use the green release lever to control the descent rate
11. Unplug the remote USB monitor
12. Turn off both wall-mounted power disconnect boxes
13. Lock catwalk door

## Appendix C: Using TheSkyX Pro to Track Geosynchronous Satellites a.k.a “Playing the Geo Satellite Game”

### C.1 Introduction

Using a telescope to track geosynchronous (geo) satellites is fundamentally straightforward. When the mount model and telescope clock are accurate, the only activity to be accomplished is to point the telescope at the satellite and turn tracking off<sup>1</sup>.

The process described in this document will guide the Operator through the steps necessary for configuring the system for geo satellite tracking. This process assumes basic operational familiarization with telescope operations and related software components. This process assumes the camera orientation is “correct.”

### C.2 Setup

The Operator will need to bring the system to steady-state for operational use before continuing with these instructions. This includes powering all components, setting camera focus, and verifying the accuracy of the mount model.

Once the system is “up and running,” the Operator should be prepared to cycle between TheSkyX Pro (GUI), STI (the telescope driver<sup>2</sup>), and MaxImDL (the camera software).



Figure C-1: GEO satellites Echostar 8 (top) and Quetzsat 1 (bottom), near star SAO 14664, shown as the rightmost bright star trail

<sup>1</sup> With tracking turned on, the stars are points of light and satellites are streaks in an image. Since geosynchronous satellites are stationary with respect to the earth (a lie, but close enough to the truth for our purposes), once the geosynchronous satellite is in the field of view, tracking must be turned off; the stars become streaks in the images.

<sup>2</sup> The SiTech telescope driver might be used instead of STI under certain circumstances. This document will refer to STI as the telescope driver, but the user should interact with STI or SiTech, as needed.

## C.3 Execution

### C.3.1 Loading TLEs

A current set of TLEs for the desired geo satellite must be loaded into TheSkyX Pro. These can be obtained from a variety of sources. One common source is [www.space-track.org](http://www.space-track.org) (registration required). It is best to use 3-line TLE's so the satellite names are shown in the GUI. Loading the TLEs can be performed by using these steps in TheSkyX Pro:

- Start the Satellites dialog in TheSkyX Pro (select the menu item Input->Satellites),
- Using the dialog, select “Remove All” to clear any previously loaded satellites,
- Using the dialog, select “Input from File” and choose the file containing the geo TLEs, and
- Close the Satellites dialog.

The Satellites dialog is shown here for reference. Note that the “Show Satellites” and “Show satellites’ paths” boxes are checked, and the Length is set to 4.00 minutes. These features are helpful for locating and tracking the desired satellites.

The bottom figure depicts a collection of geo satellites loaded and displayed in TheSkyX Pro GUI (the arc of white dots near the bottom of the image). The yellow bullseye designates the telescope’s currently position.

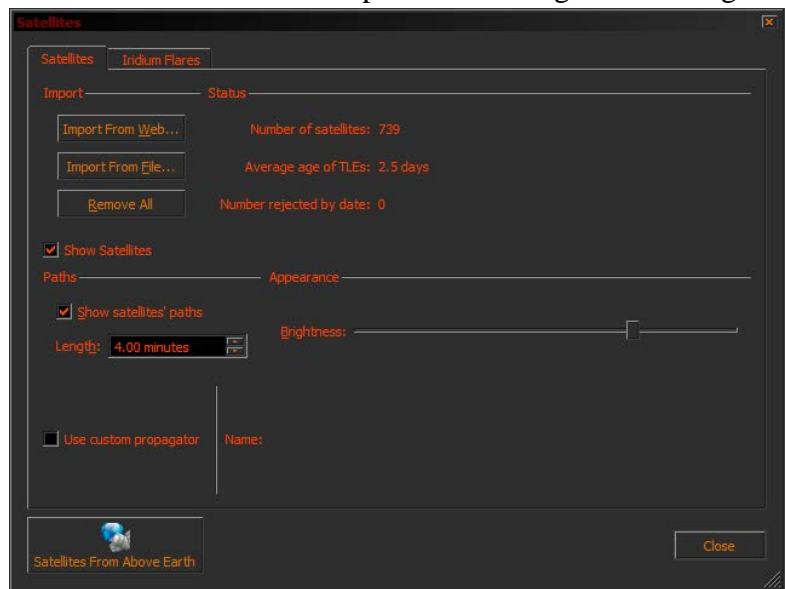


Figure C-2: SkyX Pro Satellite Dialog

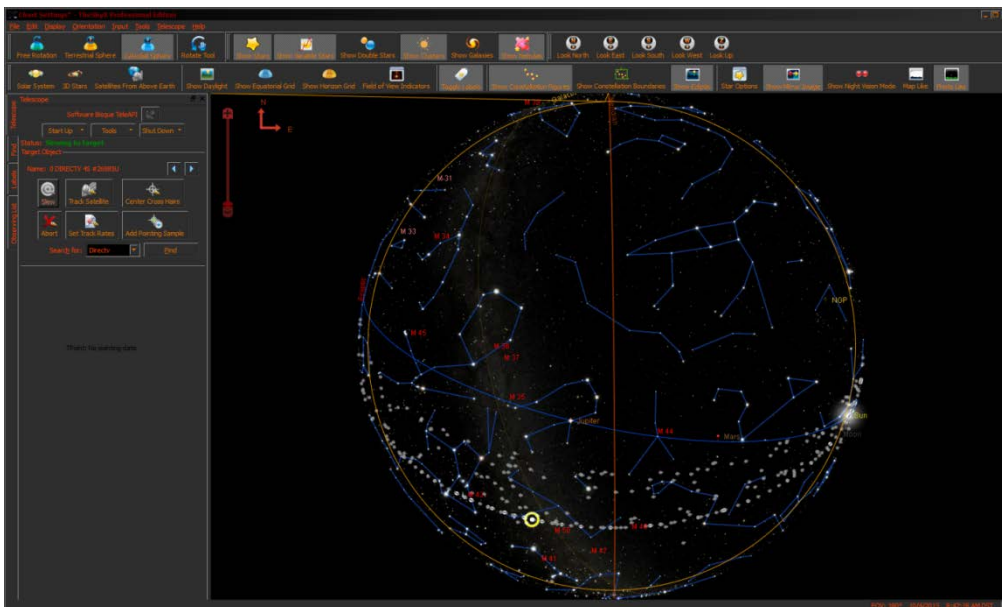
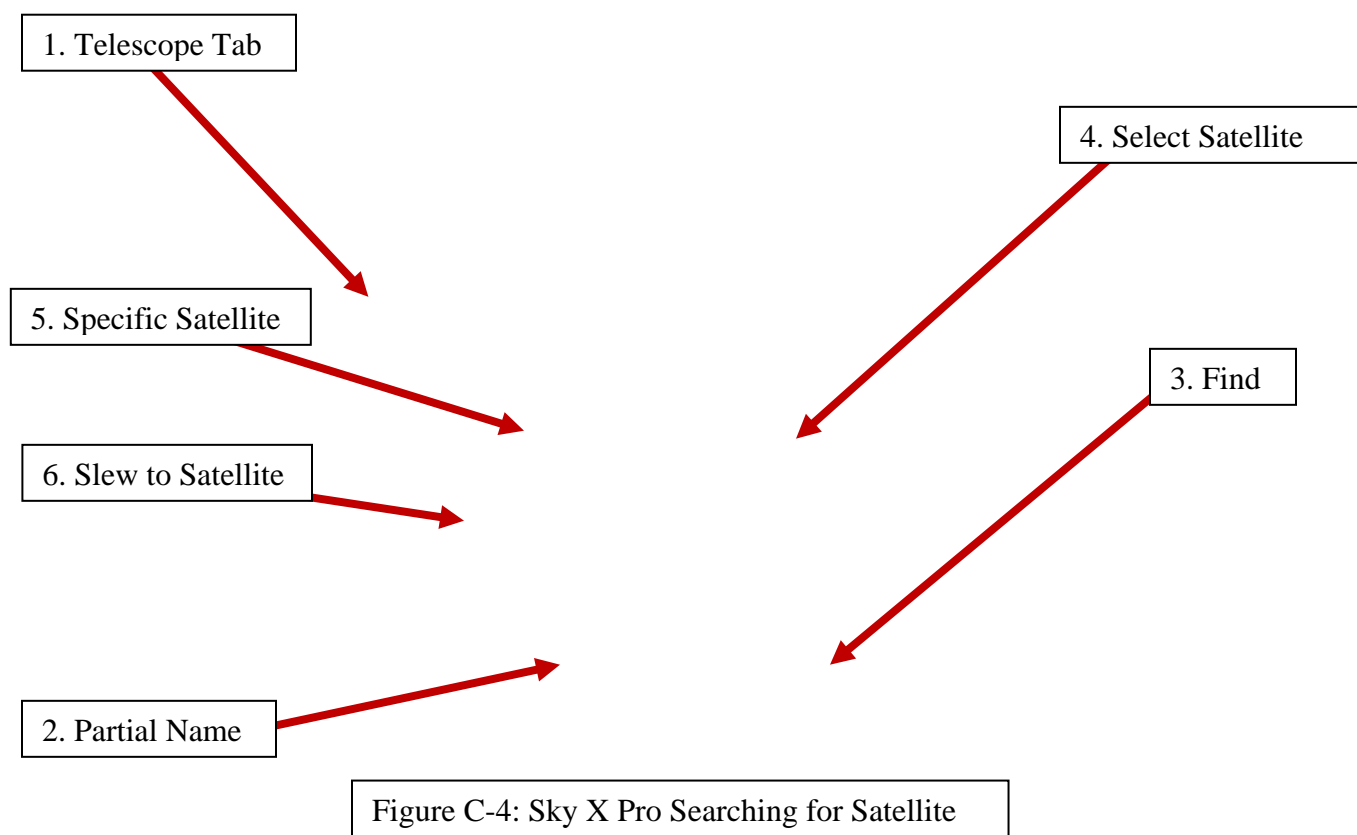


Figure C-3: SkyX Pro Satellites Loaded

### C.3.2 Selecting and Slewing to the Satellite

Once the TLE file has been loaded, finding the desired geo satellite and slewing to its location is a straightforward process. Use TheSkyX Pro to select and slew to the satellite:

1. Select the Telescope tab at the left of the screen.
2. Type (only) a portion of the satellite name into the “Search For” text entry box.  
(For example, “directv” instead of “directv 4s”)
3. Press the Find button.
4. Use the arrow selector buttons to search through the list of satellites until ...
5. ... the desired satellite name is displayed.
6. Press the Slew button to slew the telescope to the satellite. As a safety precaution, you will need to accept the slew request in the popup dialog before the telescope will execute the slew.



### C.3.3 Preparing to Follow the Satellite

Once the slew has been completed, the display in TheSkyX Pro will look similar to the top figure shown. Use the mouse and scroll wheel to center and zoom the display until the purple box representing the camera's field of view is clearly visible on the screen, and the selected satellite (red bulls-eye) and telescope position (yellow bulls-eye) are in or near the box (see bottom figure).

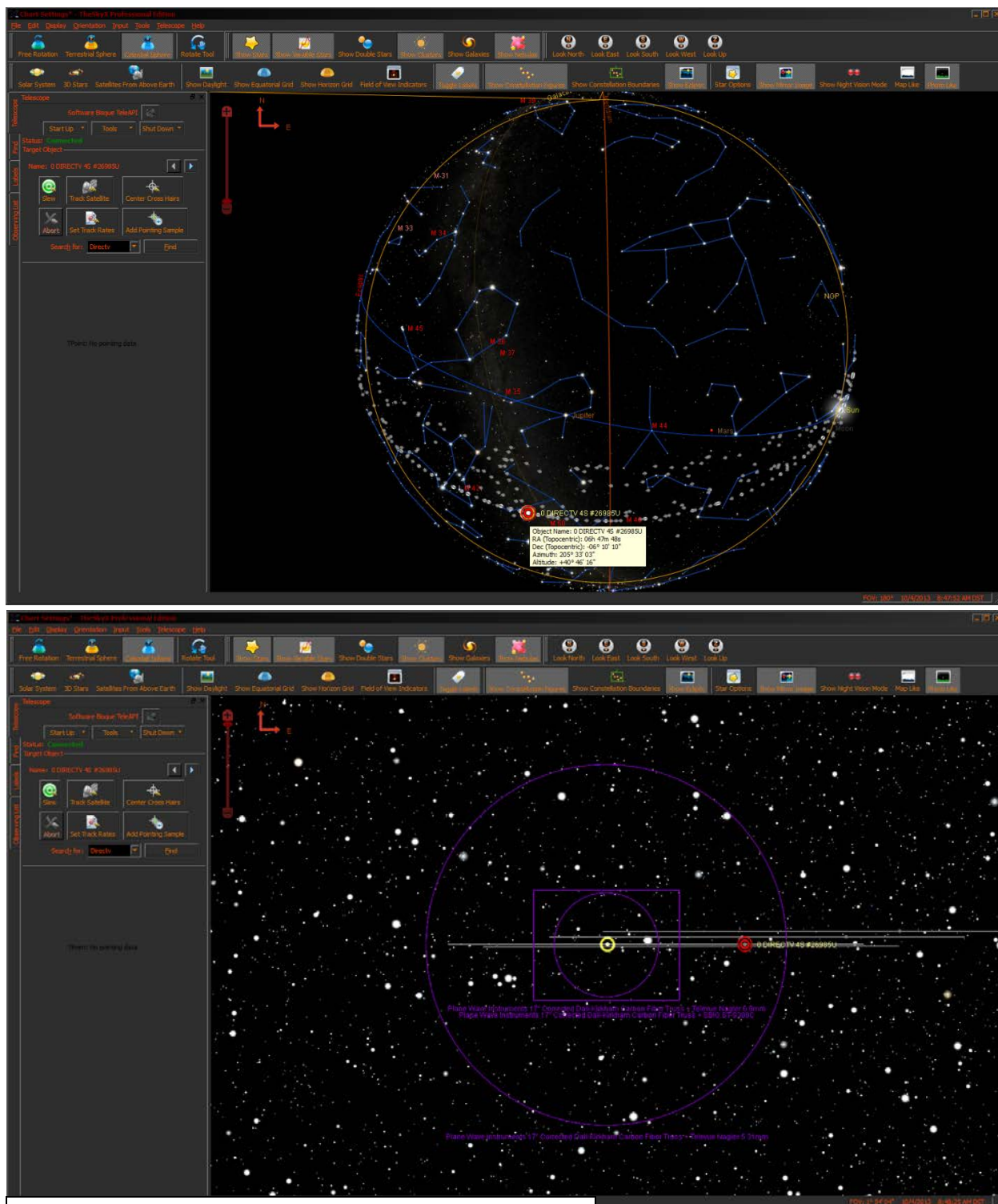


Figure C-5: Sky X Pro Zoom Out / In Target Satellite



### C.3.4 Position the Satellites for Photography

This step positions the satellites within the CCD frame for photography. This will require using three software components: TheSkyX Pro, MaxImDL, and the STI (or SiTech) telescope driver.

1. Using TheSkyX Pro:
  - a. The satellites are shown as small gray dots on their corresponding gray trails. They will be moving against the star background. Use the mouse and scroll wheel to position the satellites (near red bulls-eye) inside of the purple box, with the desired satellite trail(s) centered horizontally in the box. Hovering the mouse over the satellite, or using the left mouse button to select a satellite, will display the satellite name. This will allow confirmation of the desired satellites.
  - b. Select a position approximately 0.5—1 frame (box width) ahead of the satellite(s), on trail line (or centered among the trail lines for a group of satellites), and slew the telescope to that position.

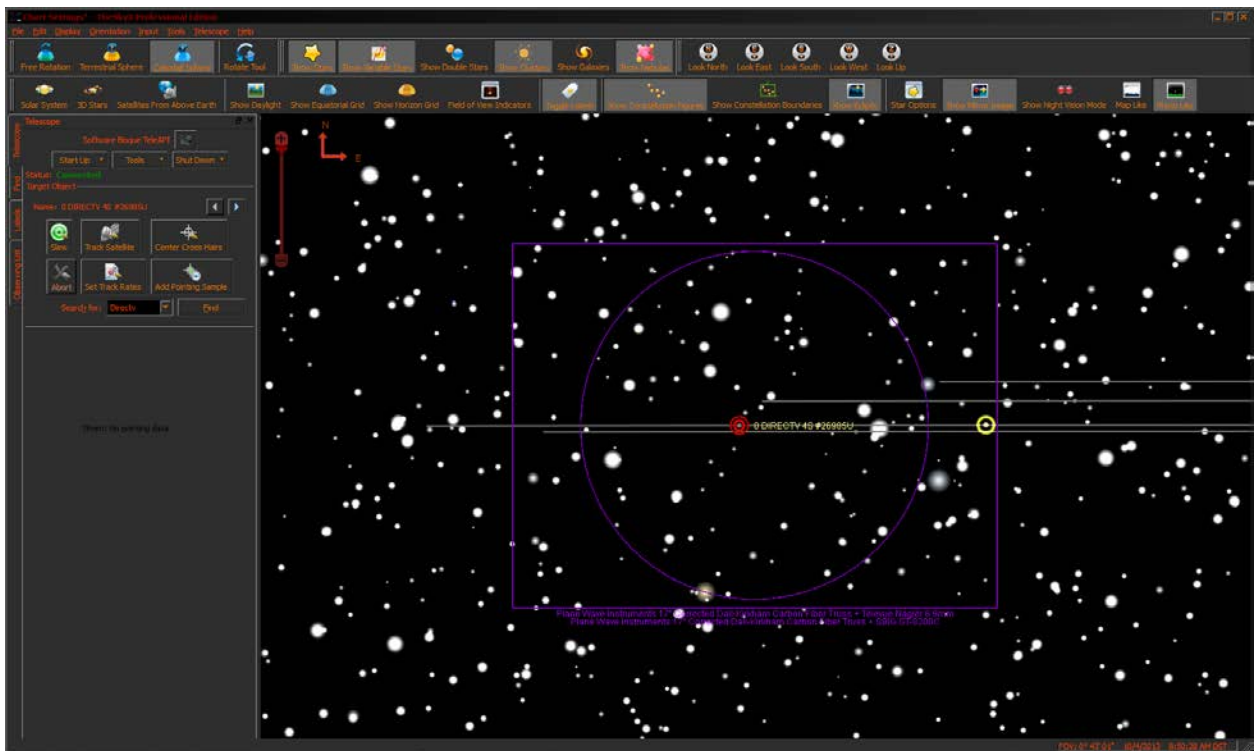
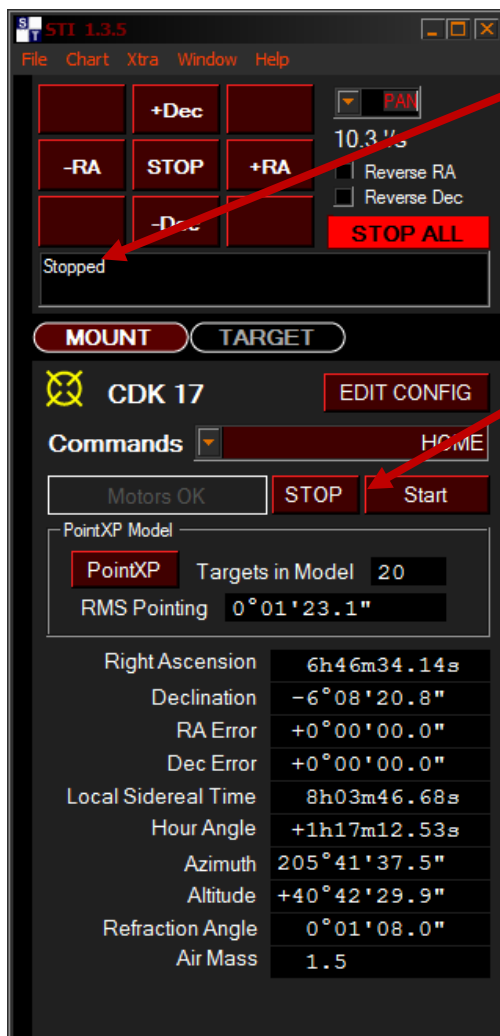


Figure C-6: Sky X Pro Position Satellite in View



2. Immediately bring STI forward, and press the “Stop” button in the center of the display to halt tracking.
  - a. The telescope will seem to move at the same rate as the satellites. In fact the satellites and telescope are stationary; the star field is moving in the background instead.
  - b. Allow the satellites to drift to the telescope’s position by alternately using the Stop and Start buttons in the center of the STI GUI to turn telescope tracking on and off. Start will allow the satellites to drift Eastward, and Stop will halt the drift. The goal is generally to center the satellite(s) in the frame.
  - c. After each Stop operation, use the left mouse button in TheSkyX Pro to drag the telescope location into the center of the box.



This status indicates when tracking is off (“Stopped”) or on (“Tracking”).

These are the Start and Stop buttons to use to turn telescope tracking on and off (to allow the satellite(s) to drift into the camera field).

Figure C-7: STI Tracking Off

- d. It may be useful to position the STI window on top of TheSkyX Pro as shown here. This allows the satellites to be visible while controlling telescope tracking.

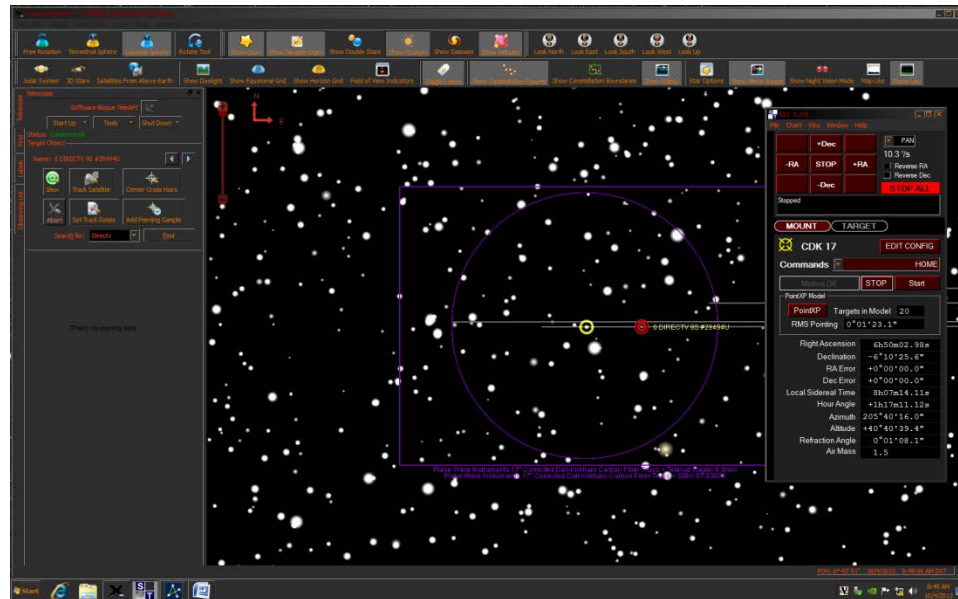


Figure C-8: Positioning Sky X Pro and STI Windows

3. When the satellites have drifted into position, use the Expose tab of the Camera Settings dialog in MaxImDL (figure not shown in this document) to take a single photo using the Visible (UV/IR Cut) filter. Suggested settings are: 10 second exposure, subframe off, binning 2, single photo, with Simple Autodark (an option in the Options pulldown) selected. A successful photo will show bright dots representing the satellites, and lines representing the trails of stars moving in the background (see the figure at the beginning of this section for an example).
4. To correct satellite positioning:
  - a. If the satellites are too high in the image, repeat step 2 as needed to drift them further down the frame. (Suggested drift time: 3-5 seconds, adjust as needed).
  - b. If the satellites are allowed to drift too far down the frame, start again at step 2.
  - c. If the satellite is too far left or right in the image, this can be corrected by repositioning the telescope further above or below the satellite trails indicated in TheSkyX Pro or using the hand controller or STI RA/Dec adjustments to carefully reposition the telescope.
  - d. In general, stars will “enter” at the bottom of the image, and scroll “up” the image. This can be observed if short consecutive frames are exposed and displayed.
  - e. Geo satellites in a recent study tended to move “up” the frame over the course of the evening. Therefore, it is better to deliberately position the satellites off-center toward the bottom of the image if data will be collected over several hours or more.
5. NOTE: for geostationary satellites, it will not be necessary to move the dome! Turn dome auto-tracking off as soon as the satellites are acquired to prevent inadvertent dome motion.
6. Geo satellites are now in position for photography.

## Appendix D: Camera Control Log

Study: \_\_\_\_\_ Date: \_\_\_\_\_

Setting: \_\_\_\_\_

Page:

Operator	
Arrive @	
Setup Start @	
Setup End @	
Leave @	

Attendant:	
Arrive @	
Shutdown @	
Shutdown Reason	
Leave @	

Sat 2 $\rightarrow$	*
Sat 1 $\rightarrow$	*

[illegible]

## Appendix E: Telescope Manning Log

[illegible]

Emergency Operator Contact Name and Number:

Email Operator / PM at end of shift: (Email address – \_\_\_\_\_)  
Include: setting, start and stop time of data collection, any comments. Please include reason why data collection was halted (end of shift, overcast skies, etc.)

## Appendix F: Magnetic Declination

Magnetic declination is the angle between magnetic north (the direction the north end of a compass needle points) and true north. The declination is positive when the magnetic north is east of true north.

Declination in Ohio is always west of true north. (Ohio Topographic Maps by Michael C. Hansen)

The declination for Dayton, Ohio is

Latitude: 39° 45' 32" N

Longitude: 84° 11' 30" W

Magnetic declination: 5° 52' WEST

Declination is NEGATIVE

BEARING is the direct compass number or angle in degrees (path) to follow to get from point A to B.

HEADING is the direction of actually travel due to obstacles between a straight line between points A and B.

Simple example: Assume the current declination value is  $-12^\circ$  (therefore  $12^\circ$  westerly), and the desired bearing is  $+72^\circ$ . A magnetic compass indicates you are traveling with a bearing of  $+72^\circ$  from magnetic north. Knowing the declination value the actual heading is  $+72^\circ + (-12^\circ) = +60^\circ$ .

In order to have the heading equal to the bearing the declination must be compensated for. Therefore  $+12^\circ$  must be added to the magnetic compass heading of  $+72^\circ$  from magnetic north which equates to  $+72^\circ + 12^\circ = 84^\circ$ .

## List of Acronyms, Abbreviations, and Symbols

CCW.....	Counter-Clockwise
C <sub>L</sub> .....	Centerline
CW .....	Clockwise
D <sub>L</sub> .....	Declination line
HQLG.....	High Quality Lithium Grease
OD .....	Outside Diameter
OTA .....	Optical Tube Assembly
PPR.....	Portable Pier